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THE DIRECT EFFECT OF POLLEN ON THE FRUIT OF THE DATE PALM [1]

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INTRODUCTION

The culture of the date palm is unique in many respects, as compared with that of the more familiar tree crops of the Temperate Zones. Not the least picturesque of the operations which characterize the industry is that of artificial pollination, necessary because of the dioecious nature of *Phoenix dactylifera* and the impracticability under commercial conditions of resorting to the natural method of wind pollination. The practice is as old as date culture itself. Obviously any direct influence which pollen may have upon the fruit is of immense practical importance to the date grower, for if available it is just as easy to use one pollen as another.

The variability of fruit-bearing palms grown from seed, the original source of all cultivated varieties, has been recognized from the beginning. It has been emphasized over and over again by the experiences of growers who have attempted to establish commercial gardens in this way and who have seldom found more than 1 or 2 per cent of such palms worthy of further propagation. Yet very little care has been used in the selection of palms for pollen. Although a few individual male offshoots came in with some of the earlier importations, at present no varieties have been established in this country. Seedling males have been used more or less indiscriminately and a good setting of fruit has generally been regarded as all that could be expected. Of course, obvious physiological differences among individual male palms have compelled attention. Because of wide variations in the time of blooming, size and number of inflorescences, quantity of pollen produced, etc., many are of little or no value.

That pollen might influence directly the fruit of the date palm has not been generally believed either by date growers or by botanists. Isolated statements without the confirmation of experimental data attract little attention. Popenoe [2] cites Schweinfurth [3] as having "declared that the characteristics of the male had an influence on the fruit which resulted." From the original it appears that Schweinfurth commented only on the variability in the size of the seed, but mentioned no other effect on the fruit. Popenoe [2] reports informally work done by Bruce Drummond when he was superintendent of the

[1] Received for publication Aug. 29, 1927; issued March, 1928.

[2] POPENOE, P. B. DATE GROWING IN THE OLD WORLD AND THE NEW. p. 108–109. Altadena, Calif. 1913.

[3] SCHWEINFURTH, G. UEBER DIE KULTUR DER DATTELPALME. Gartenflora 50: 513. 1901.

United States experiment date garden at Indio, Calif. Pollen of *Phoenix canariensis* is said to have influenced the quality of the fruit of the Rhars variety, producing a better date than was obtained on this same variety with pollen of *P. dactylifera*. In addition, on the authority of Drummond, it is reported by Popenoe that "a difference of as much as one-third in the size and of 20 days in the time of ripening seems to have been due to a change in the male used for pollinating." Drummond in his official reports to the Washington office (unpublished manuscripts) attributed marked effects on the time of ripening exerted on dates by pollen of certain male palms where both parents were cultivated varieties of *P. dactylifera*. However, in the absence of detailed records of experiments safeguarded against any possible source of error, these supposed effects remained more or less dubious, and other problems of more immediate concern in the establishment of the date industry demanded attention.

In order to throw some light on the question, a series of experiments was begun at the United States Experiment Date Garden, Indio, Calif., in the spring of 1925 and repeated on a more extensive scale in 1926.

POLLENS TESTED

As the basis of these experiments two *dactylifera* males were selected which seemed most likely to differ in their influence upon the fruit.

Fard No. 4 (fig. 1, A, and fig. 2, B) was grown from seed of imported fruit by Fred N. Johnson at Indio, Calif., and transplanted to the United States Experiment Date Garden in 1910. A description of this palm follows:

Height, 17 feet (measured to the tip of the bud as noted from the last fiber visible at the base of the youngest leaves); length of leaves, 10 to 12 feet; diameter of trunk, 26 inches (measured 3 feet above the ground and including fiber and closely pruned stubs of leaf petioles); has one offshoot remaining; in 1925 produced 14 spathes from February 6 to April 11, with two later ones the latter part of June. Though at present it is not grown in this country, the small to medium sized brownish black fruit of the Fard variety is well known to connoisseurs of dates, as it has long been imported in considerable quantities from eastern Arabia.

Mosque (fig. 1, B, and fig. 2, A) was grown from seed obtained by S. C. Mason near Kena, below Luxor, Egypt, in 1913 and planted at Indio, Calif., in 1914. A description of this palm follows:

Height, 19 feet; length of leaves, 16 to 20 feet; diameter of trunk, 31 inches; has one offshoot remaining; in 1925 produced 22 spathes from February 6 to March 24. This is a very vigorous male producing an abundance of pollen in spathes nearly twice as large as those of any other male at the United States Experiment Date Garden. Curiously enough, in view of the results obtained with pollen from this palm, Mason reports that the parent palm produced fruit which, though of excellent quality, was of only medium size.

In 1925 pollens from three other *dactylifera* palms (figs. 1 and 3) in addition to the two described were also tested, along with pollen from a *Phoenix canariensis* (Canariensis No. 1). The well-known Canary Island palm is very common in ornamental plantings in southern California. The pollen was obtained from a palm along a driveway in a neighboring community. In 1926, in addition to Mosque and Fard No. 4, pollens from 19 *dactylifera* males were tested along with pollens from two individuals of *P. canariensis*—Canariensis No. 2, a palm growing on the grounds of the Imperial County courthouse at El Centro, Calif., and Canariensis No. 3, a palm growing

FIG. 1.—Male palms whose pollens were tested: A, Fard No. 4; B, left, Deglet Noor R-6; center, Mosque

along the highway near Brawley, Calif. All of the male palms tested are of seedling origin.

Since there are likely to be differences between fruit produced on different palms of the same variety and even on the same palm to some extent between different bunches, especially as between early and late inflorescences, comparative pollinations are best made within a short range of time and on the same palm. With this in view, eight experiments were made in 1925. Seven of these were on three Deglet Noor palms, Nos. 2–8–1, 2–9–1, and 2–5–7, 15 to 16 years of age, growing at the United States Experiment Date Garden and in

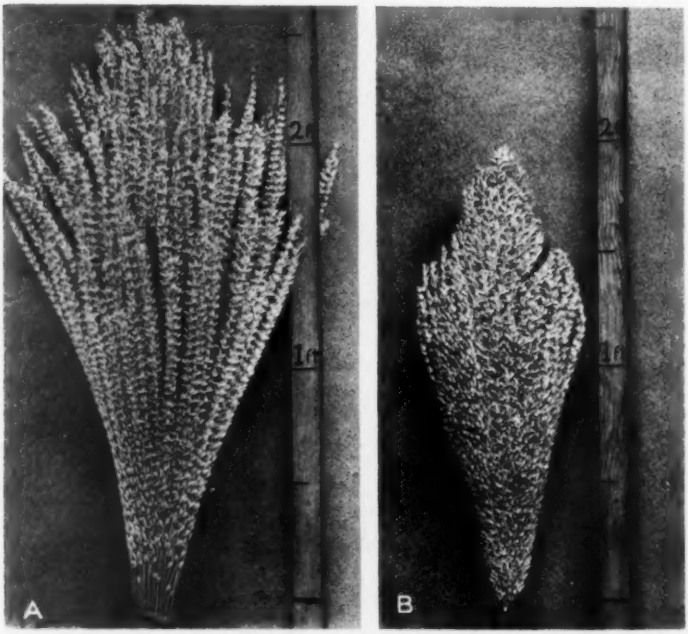

FIG. 2.—Staminate inflorescences from palms tested (the protecting sheath or spathe has been removed): A, Mosque; B, Fard No. 4

full commercial bearing. The other experiment was on Deglet Noor seedling No. 6, approximately the same age as the other three. In 1926, 19 experiments were made—10 on the 3 Deglet Noor palms mentioned above, 5 on 4 other Deglet Noor palms; 1 on Deglet Noor seedling No. 6, and 1 each on palms of the Rhars, Khadrawy, and Maktum varieties. Mosque and Fard No. 4 pollens were included in all of the experiments in 1925 and in 15 experiments in 1926; Canariensis No. 1 in 6 experiments in 1925; Canariensis No. 2 in 5 experiments and Canariensis No. 3 in 2 experiments in 1926. Along with the foregoing the other *dactylifera* pollens, comprising a total of 20 for the 2 seasons, were each tested in from 1 to 4 experiments.

In addition to those enumerated at the Indio station, nine experiments with the Mosque and Fard No. 4 pollens were made in the

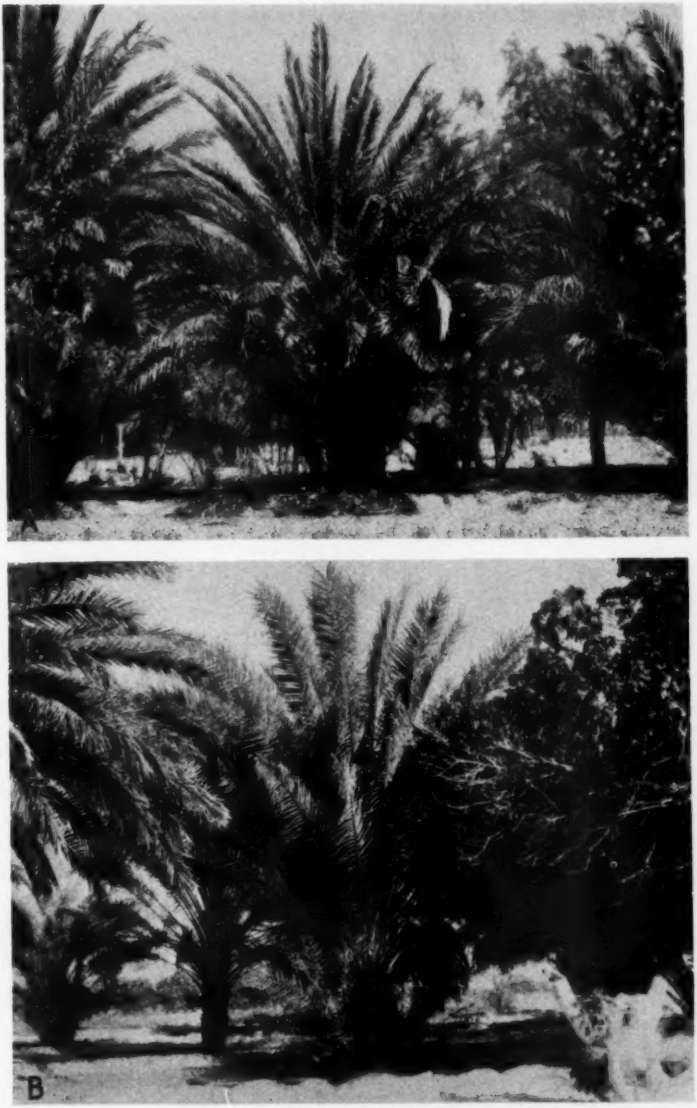

FIG. 3.—Male palms whose pollens were tested: A, Deglet Noor N-12; B, Fard FNJ-N

Salt River Valley, Ariz., in 1926—seven on two Deglet Noor palms in full bearing at the Tempe Date Garden and one on Deglet Noor and one on Iteema at the garden of the Arizona Orchards Co. The Mosque and Fard No. 4 pollens were compared directly in 30 experiments.

CARE OF POLLEN

Owing to the fine powdery nature of date pollen, special precautions are necessary in handling it. The male palms used in these tests were visited every morning and mature spathes cut as soon as they showed signs of splitting or opening. During the first season, to minimize the danger of contamination from pollen blown about in the air or transported by bees from other male palms, no spathes were allowed to mature on any male palms except those to be tested, the others being cut from the palm before opening and while still immature.

This was not done during the second season. Instead, along with improved technic in pollination and greater precautions in the field, the better method was adopted of bagging such spathes as were desired prior to opening, mostly with glassine paper bags through which the opening of the spathe could be easily observed. Each pollen was laid out to dry in shallow trays and kept locked in a separate room reached from a different entrance. To avoid storage complications most of the pollens used in only one or two experiments were gathered, prepared, and used immediately. After handling one pollen, whether cutting the spathe for storage or using it for pollination, the operator was very careful to change clothes and to wash all exposed portions of the body. Precautions were also taken with all implements used.

TECHNIC OF POLLINATION

It is difficult to bag satisfactorily an entire cluster of female flowers. When the spathe first begins to open, the basal flowers on the strands within are usually still far down in the axil of the leaf. Fortunately, the Deglet Noor produces spathes longer and narrower than most other varieties. To cover these spathes, long narrow paper bags were made of heavy brown wrapping paper, two thicknesses each, sealed separately—essentially two bags, one within the other. A close watch was kept on the growing spathes from day to day, and each flower cluster was pollinated as soon as the spathe showed the slightest tendency to crack or open. In several of the 1926 experiments the spathes were broken apart and pollination accomplished a day or two, as nearly as could be estimated, before they would have opened normally. The results of such pollinations were entirely satisfactory. In most of the other experiments at Indio in 1926 the spathes were sponged with alcohol and several days before opening covered with glassine bags, which were removed at the time of pollination.

In pollinating, a band of cotton was first tied tightly around the base of the spathe as far down in the axil of the leaf as possible. The sides of the spathe were then pulled apart and pollen applied with a tuft of cotton about the size of a walnut, three or four being placed at different elevations between the strands. After the sharp edges

were trimmed the spathe itself was left to give rigidity to the bag, which was placed over all and tied firmly to the band of cotton at the base. As a further precaution when the basal flowers were very far down in the axil of the leaf, a second band of cotton was tied around the outside and as far down at the base as it was possible to push it. The bags were examined from time to time and during the first two weeks were pushed farther down into the axil of the leaf whenever necessary to prevent exposure of the inclosed inflorescence because of the elongation of the fruit stalk.

APPLYING POLLENS FROM SEVERAL SOURCES TO THE SAME INFLORESCENCE

Under any conditions there are apt to be slight variations between the fruit of different bunches due to variations in exposure, time of blooming, etc. Hence it is very desirable for comparison to apply the different pollens on the same inflorescence. Under such conditions greater care must be used to prevent contamination, but this is partially offset by the greater efficiency of bagging, for it is possible to put cotton all around each individual strand when only a few are used and there is no danger of subsequent exposure because of the growth of the fruit stalk.

Several pollens were applied to different strands on the same inflorescence in three of the experiments on Deglet Noor in 1925 (Nos. 4, 5, and 6). In 1926 this means of comparison was used in all of the experiments except four on Deglet Noor (Nos. 1 to 4, inclusive) at the Indio station and two on Deglet Noor (Nos. 1 and 6) at the Tempe Date Garden.

In 1925 sets of three strands each were chosen and inclosed in long narrow paper bags before any pollen was applied. As additional protection, the entire inflorescence was then inclosed in a canvas hood. In pollinating, one bag was removed from under the hood and taken off the strands; pollen was applied on all the flowers with a tuft of cotton, using a superabundance of pollen; then the strands were rebagged and left outside the canvas hood until the next pollination, or about two hours, some such interval being considered desirable to permit the wind to remove pollen which might remain in suspension in the air about the inflorescence.

A NEW METHOD FOR APPLYING ANEMOPHILOUS POLLENS

In 1926 a method was worked out for applying several pollens to different strands on the same inflorescence which greatly facilitates field work and insures a minimum of contamination. This consists in sealing the pollens in small paper packets, about 2½ by 5 inches, and gluing these small packets within the larger bags, about 3 by 24 inches, at the upper or sealed end. After the large bag has been placed over the strands to be pollinated and the lower or open end plugged with cotton and tied, the pollen is released by pulling a copper wire attached to a small tuft of cotton inside the sealed packet that contains the pollen. This breaks the pollen packet and releases pollen so it falls on the female flowers. This is not done until all of the bags are in position (fig. 4), and is accomplished by holding the upper end of the bag with one hand and pulling the lower end of the copper wire with the other. The small packets used were made of heavy glassine paper, two thicknesses each sealed separately, and

before being placed within the pollination bags they were washed in a strong solution of bichloride of mercury. The 3 by 24 inch bags were similarly made of two thicknesses of glassine paper, each sealed separately, and it was possible to observe the action of the wire plunger in effecting pollination.

This method eliminates the necessity for direct contact with pollen in the field, and the pistillate flowers are exposed only during the few moments while the bags are being placed in position. As was

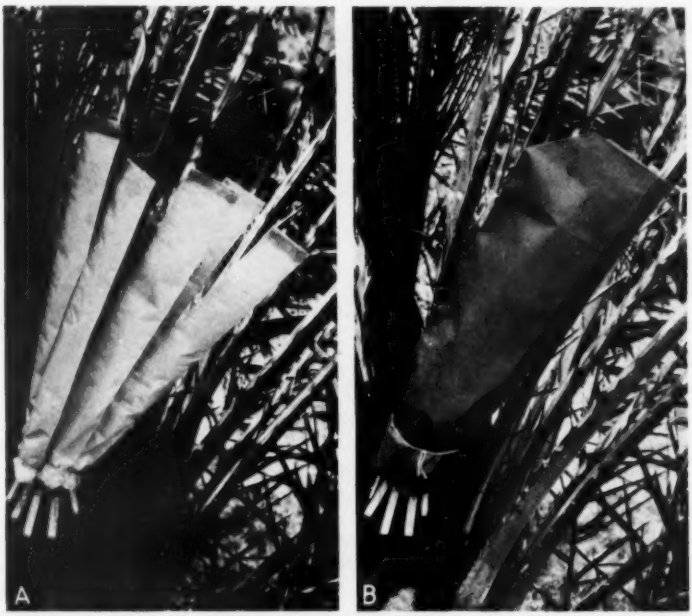

FIG. 4.—Type of bags used in experiments with different pollens on the same inflorescence. Each bag in A incloses a set of strands. Emerging from the bags at the base are the copper wires used to release pollen sealed in small packets at the upper end within. B shows a larger bag placed over the others for additional protection

done in these experiments, it is advisable to protect all the bags on a single inflorescence with a larger bag or hood.

EFFICIENCY OF TECHNIC

In the 1925 experiments two entire bunches were bagged without the application of any pollen. In one of these unpollinated treatments 1,755 dates developed, of which 14 (0.79 per cent) contained seed; in the other 1,266 dates developed, of which 32 (2.5 per cent) contained seed. In three similar unpollinated treatments in 1926 seeds were contained as follows: 5 out of 2,106, 3 out of 1,104 and 7 out of 588—almost negligible except the last, 1.2 per cent. This may be regarded as an approximate indication of the efficiency of this type of bagging; but it should also be stated that since both of the clusters in 1925 and the last mentioned in 1926 were not bagged

until the morning when the first indication of opening was observed, it is probable that in these three cases some of the pollen reached the flower clusters before they were bagged. This was indicated by the fact that the dates which contained seed were on that portion of the cluster which was first exposed by the opening of the spathe.

Each pistillate date flower contains three ovules. When pollinated, only one of these normally develops to maturity; the other two usually dry up and slough off. In most varieties if the unpollinated dates develop at all there is a slight but more or less equal development of all three ovules, sometimes crowding on the strand, resulting in a thick mass of miniature seedless dates. In the Deglet Noor variety the development of a large percentage of single dates on unpollinated inflorescences seems to be characteristic, although unpollinated inflorescences are not likely to develop as many dates as pollinated ones.

In each of the experiments at the Indio station in which several pollens were applied to the same inflorescence, an unpollinated treatment was included, to determine the degree of exposure to foreign pollen. In these, with a few exceptions, not many unpollinated dates developed, so that the proportion of dates with seed to those without would not be even an approximate indication of the efficiency of technic. However, out of 18 experiments at Indio only 4 of the unpollinated treatments developed any seed at all, and except for 4 in No. 13 in 1926 there was only 1 in each of these—No. 4 in 1925 and Nos. 14 and 17 in 1926. It does not appear, therefore, that sufficient foreign pollen could have reached the stigmas to have seriously impaired the reliability of the series of experiments. In the few cases mentioned it is very likely that air currents carried the pollen to the pistillate flowers during the few moments of exposure before they were bagged.

SEEDS PRODUCED BY CANARIENSIS POLLEN

Another indication of the care taken in handling the various pollens was afforded by a study of the seed resulting from the *canariensis* pollinations. These were found not only to average smaller than the seed resulting from any other pollination but also to have a characteristic tapering toward the basal end. (Fig. 5, A.) In the *canariensis* pollinations in 1925, of the three experiments containing this pollen on the same inflorescence with others, two had no off-type seed, but the third had 3 out of 30 which appeared to be the result of foreign pollen, or a possible contamination of 10 per cent. In the other three *canariensis* pollinations, each representing an entire bunch, the first had 3 dates which probably received foreign pollen; the second, 3; and the third only 1 out of 100 dates examined in each experiment. In 1926 out of 30 dates taken at random from each of the 7 experiments in which *canariensis* pollen was used, none of them were found to contain off-type seed. In one of these experiments (No. 3) 2 out of the 30 seeds examined were rough coated, but while slightly larger than the others there was not sufficient difference in size or shape to make it certain that other pollen had been introduced.

On the other hand, as another possible indication of the care taken in handling the various pollens, it should be noted that in all of the other experiments no seed resulted from the *dactylifera* pollinations which resembled those produced by the *canariensis*.

However, in judging the relative purity of pollination by the appearance of the seed, while the foregoing conclusions seem probable, the assumption is not justified that because a characteristic size or shape occasionally fails to appear some other pollen is necessarily responsible. Possibly the only absolute test of the purity of date pollinations would be the palms which the seed in question produced. To

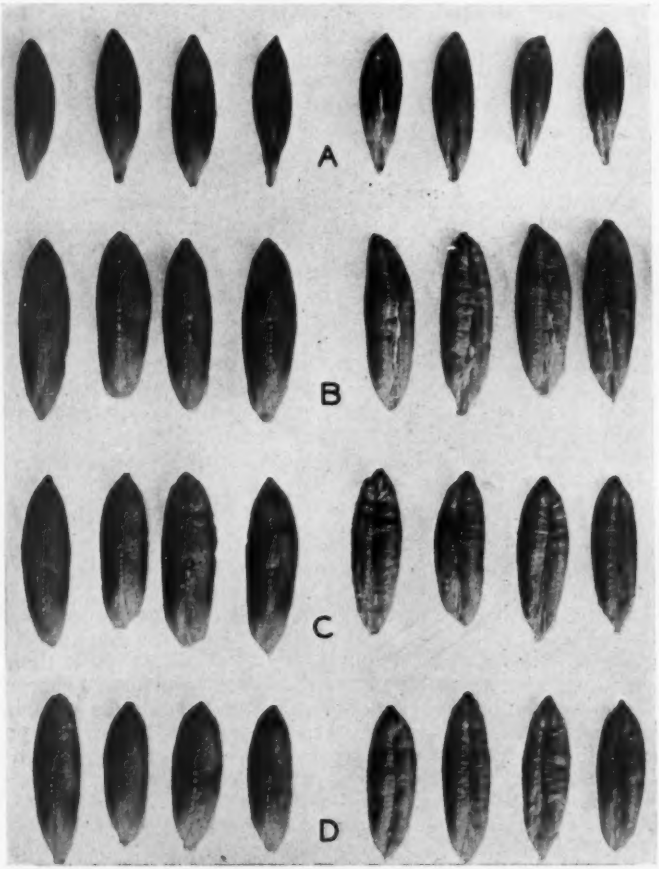

FIG. 5.—Typical Deglet Noor seeds produced on the same cluster by different pollens in experiment 5 in 1925. The male palms represented are: A, Canariensis No. 1; B, Mosque; C, Government No. 1; and D, Fard No. 4

get such proof would require many years and would even then be subject to question because of the absence of genetically pure strains of pollen.

OFF-TYPE SEEDS

Seeds entirely normal in appearance but showing marked variation from the average type in any one pollination naturally suggest

foreign pollen. On the other hand, seeds of abnormal appearance sometimes occur under such conditions as to make it very likely that some physiological disturbance in the development of the embryo and endosperm is responsible rather than another pollen. In a few of the Fard pollinations, both in 1925 and in 1926, there occurred occasionally an extra large seed, generally very irregular in shape, with a long, tapering apex more or less curved to one side; light colored; ventral surface rather flat and a ventral furrow which instead of a normal closure appeared split throughout its entire length. The fruits containing such seeds were also larger than the average and remained immature much longer, rarely ripening normally. This accounts for the delayed ripening of 1 date from Fard No. 4 pollen in experiment 4, 1 in experiment 5, 1 in experiment 9, and 2 in experiment 8. Only in two or three instances did any tendency toward this particular abnormality show in any of the other pollinations, though its occasional occurrence has been noted in various commerical gardens throughout the Coachella Valley.

Here also should be mentioned another phenomenon—the occasional appearance of one or more longitudinal ridges or "wings" on the seed. These ridges if pronounced usually produce a longitudinal depression in the flesh immediately above, which is more or less prominent until the dates begin to soften. Such seed seem to occur more commonly with pollen from some palms than with that from others, but apparently may be found now and then with any pollen. Out of the *canariensis* pollinations there were one seed in 1925 and two in 1926 which developed a longitudinal ridge but which otherwise were unmistakably typical seeds produced by *canariensis* pollen.

DEVELOPMENT AND RIPENING OF FRUIT

A good setting of fruit was obtained in all of the pollinations except the *canariensis*, which was below normal. In most of the experiments the Mosque pollen gave a little better setting than the Fard No. 4, but the difference would seldom have attracted attention in a commercial garden.

As early as the first week in June, 1925, it was evident that the dates from the *canariensis* pollinations were smaller than those from the others, and even before this the smaller size of the unpollinated dates could be observed.

By the middle of July the bulk of the Deglet Noor dates in the Coachella Valley, where these tests were initiated, have usually reached about their maximum size and begin to change in color from green to a bright coral red, commonly ranging around carnelian red (R. XIV),[4] which is characteristic of the prerip stage in this variety. During the period of color change every shade from pure green to bright red may be found at the same time on the same cluster and often on the same fruit. However, differences in the rate at which the fruit from the various pollinations took on the red color were very apparent. In fact, the earlier coloring of the fruit from pollinations with Fard No. 4 was one of the striking features of these tests. Although distinguishable in all of the experiments, it was especially obvious where the pollinations were side by side on the same bunch.

[4] All color references are from RIDGWAY, R. COLOR STANDARDS AND COLOR NOMENCLATURE. 43 p., illus. Washington, D. C., 1912. Published by the author. The color cited, "carnelian red," is quoted from Ridgway's plate 14, being indicated by R. XIV.

These differences in coloring were found to be followed by subsequent differences in ripening, so in the 1926 experiments at the Indio station detailed notes were made at a time approximately in the middle portion of the period of color change. These observations are given in Table 3. Differences in the rate of ripening of the fruit are shown in Tables 1, 2, 4, and 5.

TABLE 1.—*Ripening of the fruit of Deglet Noor palms in experiments 1, 2, 3, and 7 during the year 1925, at Indio, Calif., including the percentage ripe by September 30 and that damaged by rain October 4 and 5*

Experiment	On Deglet Noor palm No.	Pollen used	Date of pollination	Weekly pickings (ounces)															Percentage of fruit ripe Sept. 30	Percentage of fruit damaged by rain Oct. 4 and 5
					September					October					November					
				Aug. 27	3	9	17	23	30	*7	15	22	29	5	12	19	26	Total		
No. 1	2-8-1	Mosque	Mar. 2	18	30	34	111	114	150	132	44	74	52	14	...	...	...	773	59.1	3.1
		Fard No. 4	Feb. 23	69	55	51	124	113	40	12	...	...	...	...	...	...	...	464	97.4	.8
		Canariensis No. 1	Feb. 25	24	41	25	66	32	39	60	6	6	2	2	...	...	...	303	74.9	9.5
		Deglet Noor R-6	Feb. 27	77	53	67	107	84	117	98	36	51	4	...	...	...	...	694	72.7	4.3
No. 2	2-9-1	Mosque	Feb. 25	38	66	132	90	38	33	57	...	...	...	...	...	...	...	454	87.4	4.6
		Fard No. 4	Feb. 26	55	46	48	152	109	78	42	...	...	...	...	...	...	...	530	92.0	3.4
		Canariensis No. 1	Feb. 24	24	35	38	88	56	66	92	49	13	14	4	...	...	...	479	64.0	14.4
		Deglet Noor R-6	Feb. 26	35	36	49	117	108	135	172	19	...	...	...	...	...	...	671	71.5	9.7
No. 3	2-5-7	Mosque	Mar. 23	...	...	...	30	38	42	34	17	20	20	6	...	...	...	207	53.1	.9
		Fard No. 4	Mar. 19	...	...	...	80	52	92	67	15	14	3	...	...	...	...	323	69.3	1.2
		Government No. 1	Mar. 12	...	...	...	58	60	84	109	36	55	26	5	...	...	...	433	46.6	3.2
		Huey	Mar. 30	...	...	...	9	19	32	41	12	20	16	7	...	...	...	156	38.4	4.5
		Canariensis No. 1	Apr. 10	...	...	...	...	2	8	19	5	8	2	4	8	1	1	58	17.2	5.0
No. 4	2-9-1	Mosque	Mar. 21	...	...	28	93	73	119	199	51	29	33	20	...	...	...	645	48.5	21.5
		Fard No. 4	Mar. 22	...	...	41	113	62	84	62	...	...	...	...	...	...	...	362	82.8	4.9
		Huey	Mar. 26	...	...	16	28	26	58	116	4	...	...	...	...	...	...	248	51.6	29.4

* Fruit damaged by the rain on October 4 and 5 is included in the picking of October 7.

TABLE 2.—*Relative maturity of dates in experiments 4, 5, and 6 in 1925 at Indio, Calif.*

[The several pollens were applied to different strands on the same inflorescence in each experiment]

Experiment	On Deglect Noor palm No.	Pollen used	Date of pollination	Total number of fruits	August 18			August 27			September 16		
					Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)
					Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe	
No. 4	2-8-1	Mosque	Mar. 10	104	0	7	6.7	9	8	16.3	...	...	...
		Fard No. 4		57	18	5	40.3	37	10	82.5	...	...	...
		Government No. 1		124	0	5	4.0	12	5	13.7	...	...	...
		Canariensis No. 1		77	2	0	2.6	5	2	9.1	...	...	...
No. 5	2-9-1	Mosque	Mar. 14	127	0	0	0	3	0	2.4	...	...	...
		Fard No. 4		79	4	0	5.1	11	2	16.5	...	...	...
		Government No. 1		122	0	0	0	4	3	5.7	...	...	...
		Canariensis No. 1		49	0	0	0	0	0	0	...	...	...
No. 6	2-5-7	Mosque	Mar. 10	69	0	0	0	...	...	...	43	0	62.3
		Fard No. 4		84	8	10	21.4	...	...	...	84	0	100
		Government No. 1		124	0	0	0	...	...	...	80	7	70.2
		Canariensis No. 1		63	0	0	0	...	...	...	30	0	47.6

TABLE 3.—*Differences in coloring of dates in experimental pollinations during the period of transition from green to characteristic preripe color in 1926 at Indio, Calif.*

Certain applications of pollen are marked with an asterisk (*) indicating that the protective bags were partially unsealed by rain on April 5]

Experiment No., variety used, and date of observation	Date of pollination	Pollen used	Total number of fruits	Fruits showing reddish tints		Remarks (relating to color)
				Number	Per cent	
No. 1, on Deglet Noor 2-8-1, July 20.	Feb. 11	Mosque	123	66	54	Well advanced.
	Feb. 14	Canariensis No. 2	89	26	29	Faint.
	Feb. 16	Deglet Noor, N-12	100	71	71	Comparable to Fard
	Feb. 18	Fard No. 4	107	71	66	Well advanced.
	Feb. 24	(No pollen)				
	Mar. 2	Fard, FNJ-S	80	34	38	Faint.
	Mar. 6	Fard, FNJ-N	80	37	46	Do.
	Mar. 12	*Menakher No. 1	112	5	4	Do.
	Mar. 13	*Maktum No. 5	99	11	11	Do.
	Mar. 24	*Deglet Noor, R-6	104	1	1	Very faint.
No. 2a, on Deglet Noor 2-9-1, July 19.	Feb. 16	Mosque	78	22	28	Faint.
	do	Canariensis No. 3	27	8	30	Do.
	do	(No pollen)				
No. 2b, on Deglet Noor 2-9-1, July 27.	Feb. 17	Fard No. 4	72	44	61	Intermediate.
	Feb. 20	Maktum No. 5	75	25	33	Faint.
	Mar. 2	Fard, FNJ-S	96	94	98	Well advanced.
	Mar. 8	Fard, FNJ-N	80	78	98	Do.
	Mar. 10	Deglet Noor, N-10	82	32	39	Intermediate.
	Mar. 15	*Mosque	122	8	7	Very faint.
	do	*Fard No. 4	96	51	53	Faint.
	Mar. 20	*Deglet Noor, N-18	95	20	21	Very faint.
No. 3, on Deglet Noor 2-5-7, July 27.	Mar. 1	Canariensis No. 3	73	44	60	Faint.
	Mar. 9	*Mosque	98	19	19	Do.
	Mar. 10	*Fard No. 4	71	43	61	Do.
	Mar. 15	*Government No. 1	70	19	27	Very faint.
	Mar. 22	*(No pollen)				
No. 4, on Deglet Noor 2-8-1, July 16.	Feb. 11	Mosque	128	44	34	Intermediate.
		Fard No. 4	63	7	75	Well advanced
		Canariensis No. 2	94	16	17	Very faint.
		Deglet Noor, N-12	98	42	42	Intermediate.
No. 5, on Deglet Noor 2-8-1, July 27.	Mar. 20	Mosque	147	25	17	Faint.
		Fard No. 4	89	83	93	Faint, few intermediate.
		Saidy, No. 13	117	49	42	Faint.
		Deglet Noor, N-18	105	27	26	Do.
No. 6, on Deglet Noor 2-8-1, July 27.	Mar. 23	Mosque	98	20	20	Faint.
		Fard No. 4	84	55	65	Faint, few intermediate.
		Deglet Noor, R-1	109	45	41	Faint.
		Deglet Noor, R-6	127	9	7	Very faint.
No. 7, on Deglet Noor 2-9-1, July 27.	Feb. 26	Fard No. 4	94	91	97	Well advanced.
		Fard, FNJ-S	57	55	96	Do.
		Canariensis No. 2	27	18	67	Faint.
		Maktum No. 5	80	63	79	Intermediate.
		Maktum No. 6	85	81	95	A little behind Maktum No. 7.
		Maktum No. 7	91	87	96	Well advanced.
No. 8, on Deglet Noor 2-9-1, July 27.	Mar. 8	Mosque	69	24	35	Less advanced than Fard.
		Fard No. 4	83	72	87	Well advanced.
		Menakher No. 1	68	35	51	Intermediate.
		Thoory No. 20	59	33	56	Do.
		Saidy No. 25	64	35	55	Do.
		Fard, FNJ-N	83	81	97	Well advanced.
		Deglet Noor, N-9	82	46	56	Intermediate.
		Ascherasi	89	54	61	Do.
No. 9, on Deglet Noor 2-5-7, July 16.	Feb. 25	Mosque	84	12	14	Faint.
		Fard No. 4	45	17	38	Intermediate.
		Fard, FNJ-S	44	19	43	Do.
		Canariensis No. 2	57	4	7	Very faint.
		Deglet Noor, N-9	81	24	30	Faint.
No. 10, on Deglet Noor 2-8-2, July 27.	Mar. 8	Ascherasi	86	82	95	Intermediate.
		Deglet Noor, N-9	88	70	80	Do.
		Thoory No. 20	56	44	79	Do.

TABLE 3.—*Differences in coloring of dates in experimental pollinations during the period of transition from green to characteristic prepipe color in 1926 at Indio, Calif.*—Continued

Experiment No., variety used, and date of observation	Date of pollination	Pollen used	Total number of fruits	Fruits showing reddish tints		Remarks (relating to color)
				Number	Per cent	
No. 11, on Deglet Noor 2-9-2, July 27.	Mar. 9	Fard No. 4	45	40	89	Intermediate.
		Fard, FNJ-N	57	53	93	Do.
		Saidy No. 25	92	62	67	Do.
		Deglet Noor, N-9	76	37	49	Faint.
No. 12, on Deglet Noor 2-6-3, July 27.	Mar. 9	Maktum No. 5	99	21	21	Faint.
		Maktum No. 6	101	29	29	Do.
		Thoory No. 20	102	13	13	Very faint.
No. 13, on Deglet Noor seedling No. 6, July 19.	Mar. 10	Mosque	52	25	48	Less advanced than Fard.
		Fard No. 4	87	87	100	Well advanced.
		Canariensis No. 2	99	90	91	Less advanced than Fard.
No. 14, on Rhars, 1-8-6, July 13.	Feb. 15	Mosque	23	0	0	
		Fard No. 4	16	9	56	
		Canariensis No. 2	50	19	38	Prepipe color, yellow.
No. 15, on Khadrawy, 2-1-8, July 27.	Mar. 24	Mosque	38	8	21	
		Fard No. 4	39	21	54	Prepipe color, yellow.
No. 16, on Maktum, 2-7-7, July 27.	Mar. 13	Mosque *	57	10	18	
		Fard No. 4	93	57	61	
		Maktum No. 5	60	21	35	Prepipe color, yellow.
No. 17, on Deglet Noor 2-4-4, Aug. 19.	Apr. 12	Mosque	56	45	80	Faint.
		Fard RB No. 1	69	67	97	Intermediate.
No. 18, on Deglet Noor 2-4-4, Aug. 19.	Apr. 14	Mosque	45	37	82	Faint.
		Fard A-21-2-32	50	48	96	Intermediate.

* Two strands only, one having been broken off.

TABLE 4.—*Progressive ripening of dates resulting from experimental pollinations in 1926 at Indio, Calif.*

Experiment No. and variety used	Date of pollination	Pollen used	Total number of fruits	Aug. 17			Aug. 18			Aug. 27			Sept. 3			Sept. 13			Sept. 14			Sept. 30		
				Number of fruits			Number of fruits			Number of fruits			Number of fruits			Number of fruits			Number of fruits			Number of fruits		
				Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)	Ripe	Partly ripe	Fruits ripe and partly ripe (per cent)
No. 1, Deglet Noor 2-8-1	Feb. 11	Mosque	115	24	7	27	----	----	----	70	12	71	99	3	89	109	6	100	----	----	----	----	----	----
	Feb. 14	Canariensis No. 2	85	15	3	21	----	----	----	45	5	59	59	4	74	71	4	88	----	----	----	84	1	100
	Feb. 16	Deglet Noor N-12	95	36	3	41	----	----	----	77	3	84	92	1	98	95	----	100	----	----	----	----	----	----
	Feb. 18	Fard No. 4	106	30	9	37	----	----	----	75	13	83	99	2	95	104	2	100	----	----	----	----	----	----
	Mar. 2	Fard FNJ-S	87	24	3	31	----	----	----	67	6	84	80	1	93	85	2	100	----	----	----	----	----	----
	Mar. 6	Fard FNJ-N	79	19	5	30	----	----	----	65	2	85	71	2	92	78	0	99	----	----	----	79	----	100
	Mar. 12	Menakher No. 1	109	4	2	6	----	----	----	24	12	33	39	7	42	80	13	85	----	----	----	109	----	100
	Mar. 13	Maktum No. 5	99	10	1	11	----	----	----	29	6	35	51	2	54	80	4	85	----	----	----	99	----	100
	Mar. 24	Deglet Noor R-6	96	2	0	2	----	----	----	5	7	13	13	8	22	48	8	58	----	----	----	95	0	99
No. 2a, Deglet Noor 2-9-1	Feb. 16	Mosque	76	9	5	18	----	----	----	26	11	40	51	5	74	71	3	97	----	----	----	76	----	100
	...do...	Canariensis No. 3	26	8	3	42	----	----	----	17	1	69	19	1	77	21	3	92	----	----	----	26	----	100
	Feb. 17	Fard No 4	70	28	11	56	----	----	----	62	0	89	68	0	97	70	----	100	----	----	----	----	----	----
	Feb. 20	Maktum No 5	75	11	8	25	----	----	----	35	12	63	60	3	84	72	2	99	----	----	----	75	----	100
No. 2b, Deglet Noor 2-9-1	Mar. 2	Fard FNJ-S	94	30	8	40	----	----	----	87	4	97	92	0	98	93	0	99	----	----	----	94	----	100
	Mar. 8	Fard FNJ-N	79	20	8	35	----	----	----	60	5	82	72	2	94	79	----	100	----	----	----	----	----	----
	Mar. 10	Deglet N-10	79	11	5	20	----	----	----	24	4	35	37	5	53	58	7	82	----	----	----	79	----	100
	Mar. 15	Mosque	120	0	2	2	----	----	----	15	6	18	26	10	30	55	19	62	----	----	----	120	----	100
	...do...	Fard No. 4	95	11	6	18	----	----	----	36	8	46	61	21	86	93	2	100	----	----	----	----	----	----
	Mar. 20	Deglet Noor N-18	94	3	0	3	----	----	----	11	5	17	26	7	35	40	8	61	----	----	----	87	3	96
No. 3, Deglet Noor 2-5-7	Mar. 1	Canariensis No. 3	70	3	1	6	----	----	----	8	8	23	15	6	30	37	8	64	----	----	----	62	1	90
	Mar. 9	Mosque	90	0	0	0	----	----	----	3	4	8	7	3	11	37	7	49	----	----	----	66	14	89
	Mar. 10	Fard No. 4	71	1	3	6	----	----	----	18	7	35	30	3	46	38	4	59	----	----	----	69	1	99
	Mar. 15	Government No. 1	68	0	0	0	----	----	----	5	8	19	11	5	24	26	5	46	----	----	----	65	1	97
No. 4, Deglet Noor 2-8-1	Feb. 11	Mosque	122	57	5	51	----	----	----	113	4	96	122	0	100	----	----	----	----	----	----	----	----	----
		Fard No. 4	60	50	7	95	----	----	----	59	0	98	59	0	98	60	----	100	----	----	----	----	----	----
		Canariensis No. 2	91	13	6	21	----	----	----	34	6	44	41	2	47	63	2	71	----	----	----	89	2	100
		Deglet Noor N-12	54	45	5	93	----	----	----	54	----	100	----	----	----	----	----	----	----	----	----	----	----	----

TABLE 4.—*Progressive ripening of dates resulting from experimental pollinations in 1926 at Indio, Calif.*—Continued

Experiment No. and variety used	Date of pollination	Pollen used	Total number of fruits	Aug. 17			Aug. 18			Aug. 27			Sept. 3			Sept. 13			Sept. 14			Sept. 30		
				Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)	Number of fruits		Fruits ripe and partly ripe (per cent)
				Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe		Ripe	Partly ripe	
No. 5, Deglet Noor 2-8-1	Mar. 20	Mosque	146	3	1	3	----	----	----	15	6	14	34	4	26	51	16	46	----	----	----	142	2	99
		Fard No. 4	86	12	4	19	----	----	----	37	6	50	56	4	70	77	2	92	----	----	----	85	0	99
		Saidy No. 13	116	8	3	9	----	----	----	28	6	29	36	3	34	58	17	65	----	----	----	116	----	100
		Deglet Noor N-18	102	4	0	4	----	----	----	11	2	13	23	3	25	51	7	57	----	----	----	93	4	95
No. 6, Deglet Noor 2-8-1	Mar. 23	Mosque	98	0	2	2	----	----	----	9	6	15	19	3	22	40	7	48	----	----	----	87	6	95
		Fard No. 4	83	8	7	18	----	----	----	27	12	47	40	7	57	71	6	93	----	----	----	83	----	100
		Deglet Noor R-1	107	3	3	6	----	----	----	19	10	27	31	7	36	53	14	63	----	----	----	106	1	100
		Deglet Noor R-6	122	1	0	1	----	----	----	2	1	2	5	0	4	20	11	25	----	----	----	104	9	93
No. 7, Deglet Noor 2-9-1	Feb. 26	Fard No.4	94	21	7	30	----	----	----	71	13	89	87	4	97	92	0	98	----	----	----	94	----	100
		Fard FNJ-S	55	15	8	42	----	----	----	45	6	93	53	0	96	54	0	98	----	----	----	55	----	100
		Canariensis No. 2	25	0	1	4	----	----	----	5	0	20	5	2	28	12	1	52	----	----	----	25	----	100
		Maktum No. 5	79	8	4	15	----	----	----	35	7	53	49	7	71	75	2	97	----	----	----	79	----	100
		Maktum No. 6	83	10	5	18	----	----	----	52	12	77	70	7	93	82	0	99	----	----	----	83	----	100
		Maktum No. 7	92	7	11	20	----	----	----	60	14	80	83	4	95	89	1	98	----	----	----	92	----	100
No. 8, Deglet Noor 2-9-1	Mar. 8	Mosque	67	2	2	6	----	----	----	17	7	36	30	2	48	44	3	70	----	----	----	62	2	96
		Fard No. 4	82	15	3	22	----	----	----	37	3	49	43	4	57	56	11	82	----	----	----	79	1	98
		Menakher No. 1	67	0	1	1	----	----	----	14	10	36	29	12	61	50	5	82	----	----	----	63	0	94
		Thoory No. 20	60	5	3	13	----	----	----	20	6	43	37	12	82	51	2	88	----	----	----	60	----	100
		Saidy No. 25	58	0	4	7	----	----	----	20	7	47	22	10	55	47	7	93	----	----	----	58	----	100
		Fard FNJ-N	82	10	4	17	----	----	----	44	13	70	72	1	89	80	1	99	----	----	----	81	1	100
		Deglet Noor N-9	83	3	3	7	----	----	----	25	7	39	35	2	45	54	6	72	----	----	----	83	----	100
		Ascherasi	90	6	8	15	----	----	----	31	23	60	55	14	77	83	5	98	----	----	----	89	1	100
No. 9, Deglet Noor 2-5-7	Feb. 25	Mosque	82	5	9	17	----	----	----	39	9	59	55	4	72	73	6	96	----	----	----	81	1	100
		Fard No 4	44	9	12	48	----	----	----	33	5	86	41	1	95	43	0	98	----	----	----	43	0	98
		Fard FNJ-S	42	9	9	43	----	----	----	32	4	86	39	2	97	41	0	98	----	----	----	41	0	98
		Canariensis No. 2	57	0	0	0	----	----	----	21	4	44	27	1	49	36	10	81	----	----	----	57	----	100
		Deglet Noor N-9	81	4	11	19	----	----	----	36	5	51	44	4	59	72	4	94	----	----	----	81	----	100

No 10, Deglet Noor 2-8-2	Mar. 8	Ascherasi	83	13	15	34				60	13	88	76	6	99	83		100						
		Deglet Noor N-9	88	12	6	20				47	14	69	62	10	82	78	4	93				88		100
		Thoory No. 20	55	14	6	36				40	5	82	51	3	98	55		100						
No. 11, Deglet Noor 2-9-2	Mar. 9	Fard No. 4	42	19	8	64				37	0	88	38	0	90	40	0	95				42		100
		Fard FNJ-N	57	18	7	44				55	1	98	56	1	100									
		Saidy No. 25	92	7	11	20				57	16	79	82	2	91	90	0	98				91	0	99
		Deglet Noor N-9	76	2	6	11				46	5	67	64	7	93	73	2	99				76		100
No. 12, Deglet Noor 2-6-3	do	Maktum No. 5	95	2	0	2				5	2	7	17	8	26	41	9	53				94	1	100
		Maktum No. 6	93	2	2	4				5	5	11	19	6	27	48	12	65				92	0	99
		Thoory No. 20	99	1	1	2				3	5	8	20	4	24	44	19	63				99		100
No. 13, Seedling 20-6	Mar. 10	Mosque	52	9	2	21				17	2	36	25	6	60	42	2	85				52		100
		Fard No. 4	76	16	6	29				38	5	57	52	5	75	69	5	97				76		100
		Canariensis No. 2	98	3	3	6				8	1	9	20	1	21	30	8	39				59	8	68
No. 14, Rhars 1-8-6 [a]																								
No. 15, Khadrawy 2-1-8	Mar. 24	Mosque	36				5	2	19															
		Fard No. 4	39				17	2	49															
		Mosque [b]	57	0	0	0							0	5	9	10	13	40				45	3	84
No. 16, Maktum 2-7-7	Mar. 13	Fard No. 4	93	2	6	9							35	26	66	72	14	92				93		100
		Maktum No. 5	60	0	2	3							18	0	30	34	5	65				58	1	98
No. 17, Deglet Noor 2-4-4	Apr. 12	Mosque	56																0	3	5	29	19	86
		Fard RB No. 1	69																2	22	35	61	6	97
No. 18, Deglet Noor 2-4-4	Apr. 14	Mosque	45																1	2	7	21	15	80
		Fard A-21-2-32	47																12	12	51	43	3	98

[a] All the dates ripened before the first notes on maturity were made.

[b] Two strands only.

TABLE 5.—*Relative maturity of dates resulting from experimental pollinations in the Salt River Valley, Ariz., in 1926*

[Experiments 1–7 were at the Tempe Date Garden, and experiments 8 and 9 were at the garden of the Arizona Orchards Company. Pollens from different sources were applied on the same bunch in each experiment except 1 and 6]

Experiment No., variety used, and date of observation	Pollen used	Date of pollination	Total number of fruits	Number of fruits		Fruits ripe and partly ripe (per cent)
				Ripe	Partly ripe	
No. 1, Deglet Noor No. 1, Sept. 20.	Mosque	Mar. 30	93	27	25	56
	Fard No. 4	do	47	31	13	94
No. 2, Deglet Noor No. 1, Sept. 20.	Mosque	do	68	22	12	50
	Fard No. 4	do	33	18	9	82
No. 3, Deglet Noor No. 1, Sept. 20.	Mosque	Mar. 31	55	17	15	58
	Fard No. 4	do	59	49	4	90
No. 4, Deglet Noor No. 1, Sept. 20.	Mosque	Mar. 30	45	13	15	62
	Fard No. 4	do	68	51	14	96
	Fard FNJ–S	do	71	43	13	79
	Fard FNJ–N	do	18	16	1	94
No. 5, Deglet Noor No. 2, Sept. 21.	Mosque [a]	do	44	17	8	57
	Fard No. 4	do	70	39	18	82
	Fard FNJ–N	do	61	34	20	89
	Fard FNJ–S [b]	do	56	36	9	80
No. 6, Deglet Noor No. 2, Sept. 21.	Mosque	do	50	11	13	48
	Fard No. 4	do	64	20	29	77
	Fard FNJ–S	Mar. 31	44	17	12	66
No. 7, Deglet Noor No. 2, Sept. 21.	Mosque	Mar. 30	57	10	8	32
	Fard No. 4	do	45	18	14	71
No. 8, Deglet Noor, Sept. 22.	Mosque	Mar. 29	51	0	0	0
	Fard No. 4	do	50	13	5	36
No. 9, Iteema, Sept. 22.	Mosque	do	19	0	2	11
	Fard No. 4	do	28	[c] 9	1	36

[a] Two strands.
[b] One strand.
[c] Six of these had already been picked, but the calyxes remaining left no doubt about it.

In experiments 1, 2, 3, and 7 in 1925, in which each of the several pollens was applied to an entire inflorescence, weekly pickings of ripe fruit were made. (Table 1.) In experiment 8 no record of the ripening was kept, but it was very apparent that the fruit from the Fard No. 4 pollination matured earlier than that from Mosque. In all of the other experiments the record is based on the total number of dates on three typical strands from each pollination—all that were pollinated where several pollens were applied to the same inflorescence—and each observation includes the actual number of dates that were ripe or had already ripened and the number that were partly ripe.

DAMAGE FROM RAIN, FUNGI, AND LOW HUMIDITY

In 1925 the normal seasonal ripening was interrupted on October 4 and 5 by a heavy rain which caused more or less damage to fruit in the preripe stage just before the final color change from red to amber. No appreciable injury was done except in experiments 1, 2, 3, and 7. The damaged fruit, which normally would have ripened some weeks later, was picked within a few days and weighed separately, but entered in the total production. The weights were found to be about 20 per cent heavier than for an equal number of ripe dates, but this was probably more than offset by the proportion of fruits which fell

to the ground before they could be picked. Since the fruit affected had not begun to ripen, the relative damage from the rain affords a partial index to the maturity of the dates from the various pollinations. Of course the position and exposure of the different bunches also had some influence in this connection, but, as is shown in the last column of Table 1, the damage to the fruit from Fard No. 4 pollen was very low in every instance.

Following in the wake of the rain a week or so later, a period of cloudy weather accompanied by high humidity fostered a fungus which caused the development of soft rot, dates in the prerip stage having been chiefly affected. No account of the loss from this source could well be taken in the total production, as much of the rotting fruit fell to the ground from day to day and no attempt was made to pick any of it. However, the ripening had progressed so far that the loss was negligible except in experiment 3, and even in this the fruit from Fard No. 4, having nearly all ripened, was practically unaffected, though the loss of that from Mosque was estimated roughly at about 20 per cent and that from Canariensis No. 1 at about 50 per cent. Because of this unrecorded loss of fruit which would have ripened later, it is evident that in a normal season the actual percentage of early ripening fruit would probably have been less for all of these pollinations except the Fard No. 4.

In the Deglet Noor variety a small percentage of premature shriveling is not uncommon as the fruit ripens. In 1926 the season was earlier than usual, and the low humidity prevailing as the dates began to ripen produced an unusual proportion of shriveling throughout the Coachella Valley. In a few of the experiments at the Indio station as much as 5 to 10 per cent of the fruit was affected, but taking the experiments as a whole, fortunately very little appeared. In recording the ripening, fruit which shriveled before the final color change was discounted and eliminated from the total, but otherwise it was counted as ripe. Since there was no consistent tendency for more of this shriveling to appear in the fruit from one pollen than in that from another, the reliability of a series of experiments would not be appreciably affected.

FACTORS OTHER THAN POLLEN AFFECTING TIME OF RIPENING

Of the factors other than pollen which possibly may affect the time of ripening of the fruit, many, such as fertilizer, irrigation, and pruning, have not yet been subjected to intensive study, but they would have no direct bearing on the evidence presented here because they would affect equally all of the fruit on an individual palm.

In considering the ripening data, the effect of the earliness or lateness of the season should be borne in mind. Dates which begin to mature in the extreme heat of late summer ripen much more rapidly than those which mature later in the cooler fall weather. Hence, if the ripening begins only a week earlier, the last of the crop may be off the palms as much as a month earlier, the tapering effect of cooler weather being cut short. This is what occurred in 1926. Consequently, an early season tends to lessen differences in the time of ripening due to pollen, whereas a late season accentuates them.

Since the normal duration of the flowering season for an individual palm of the Deglet Noor variety is about six or seven weeks, rather

longer than that of most other varieties, it is important to consider the differences in ripening which may be due to differences in the time of blooming. To determine whether such differences exist, a record was kept in 1925 of the inflorescences on four Deglet Noor palms in commercial bearing, the same pollen being used on all of the flower clusters on each palm. There was an average difference of six weeks and four days between the opening of the first and the last spathes. Weekly pickings of ripe fruit from each cluster were made, from which it appeared that there was an average difference of approximately three weeks between the initial ripening of the first and the last clusters.

A comparison of the time of ripening of the fruit with respect to the time of pollination in Tables 1, 3, and 4 affords additional data. For instance, in Table 4, while the pollination with Mosque in experiment 2a was a month earlier than that with Mosque in experiment 2b, the actual difference in the time of ripening of the fruit was only about 12 days. Approximately the same difference is apparent in the results obtained with Fard No. 4 in these two experiments. On the other hand, the fruit from the pollination with Fard No. 4 in experiment 2b ripened very nearly on a par with that from the Mosque pollination in experiment 2a, though there was a month difference in the time of pollination.

Here again other factors cause variation. From an inspection of date gardens throughout the Coachella Valley it was evident that the differences in the time of ripening between the first and the last clusters on individual palms was much less in warmer localities where all the ripening was earlier, being in some cases almost negligible from a casual inspection. On the other hand, in localities where all the ripening was later, the differences were more in contrast than they were at the Indio station, in some instances the first clusters being practically stripped of fruit before any pickings were made from the last ones.

COMPARISON OF SIZES OF FRUITS AND SEEDS

In 1925 measurements were made in experiments 1, 2, 3, 7, and 8 of the fruits and seeds of 100 ripe dates, taken at random from not less than four pickings between September 1 and October 15. In experiments 4, 5, and 6 fewer than 100 dates were available, as indicated in the tabulations, all of which were measured at the same time after all the fruit had ripened. These measurements are given in Tables 6, 7, and 8. Similar measurements for the 1926 experiments are given in Tables 8 to 11, which, except as indicated, represent 30 dates from each pollination after all of the fruit had been picked. Each 30 were selected at random except that no abnormal fruits or seeds were measured. Those not measured were mostly deformed dates or those where two developed in the same calyx; in the seed, those imperfectly developed, as indicated by a small formless endosperm or by an exaggerated development all out of proportion. No doubtful specimens were excluded.

TABLE 6.—*Length of date fruits in the 1925 experiments at Indio, Calif.*

Experiment	Number of fruits measured	Pollen used	Measurements (millimeters) and frequencies																					Mean
			30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49		
No. 1	100	Mosque						1		1		7	12	22	25	18	13	1						41.68
		Fard No. 4					1		2	8	12	24	24	17	8	2	1			1				39.64
		Deglet Noor R-6								5	10	17	27	24	12	5								40.11
		Canariensis No. 1					1	4	12	25	21	26	6	3	2									37.90
No. 2	100	Mosque								1	2	14	30	19	17	11	5	1						40.90
		Fard No. 4						1	4	14	17	19	21	12	8	2		2						39.28
		Deglet Noor R-6							1		7	21	27	24	17	2		1						40.30
		Canariensis No. 1		2	1		1	9	12	31	23	12	7	1	1									37.27
No. 3	100	Mosque									5	7	15	25	26	15	6	1						41.34
		Fard No. 4			2	2	1		2	8	24	27	27	7										38.64
		Government No. 1								2	5	22	31	25	10	5								40.22
		Canariensis No. 1				2	1	3	14	10	27	28	12	2	1									38.01
		Huey						1	1	2	6	15	22	31	15	7								40.40
No. 4	30	Mosque												1	3	4	1	12	3	4		2		44.90
		Fard No. 4							1	1	3	5	3	5	4	5	1	1				1		40.93
		Government No. 1										1	1		3	5	10	7		3				43.86
		Canariensis No. 1					1	1	1	6	5	6	7	2	1									38.50
No. 5	40	Mosque								1	1	2	8	9	14	4		1						41.17
		Fard No. 4					2	1	4	2	9	9	5	4	2	2								38.70
		Government No. 1									1	6	11	5	10	6	1							40.97
		Canariensis No. 1		1	1	1	3	7	4	6	11	5	1											36.55
No. 6	45	Mosque						2	6	6	5	9	9	4	3	1								38.71
		Fard No. 4					2	1	5	8	8	9	5	5	1	1								38.31
		Government No. 1							1	1	2	7	13	6	10	1	4							40.60
		Canariensis No. 1	1		1	2		7	8	11	13	1			1									36.51
No. 7	100	Mosque									3	3	8	14	30	19	15	7		1				42.24
		Fard No. 4				1	1	2	1	5	9	22	24	21	10	4								39.71
		Huey			1						1	2	2	1	4	18	25	21	16	5	2	2		44.21
No. 8	100	Mosque											1		2	5	11	22	20	19	14	6		45.92
		Fard No. 4							1	1	4	11	21	27	23	11	1							40.84

TABLE 7.—*Length of seeds of date fruits in the 1925 experiments at Indio, Calif.*

Experiment	Number of seeds measured	Pollen used	Measurements (millimeters) and frequencies																					Mean
			16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	39	
No. 1	100	Mosque								1	1	4	8	18	22	20	17	7	1	1				28.29
		Fard No. 4		1				1	16	27	23	22	5	3					1		1		1	23.92
		Deglet Noor R-6						1		3	11	24	36	18	7									25.72
		Canariensis No. 1				15	31	28	15	7	2			1	1									20.87
No. 2	100	Mosque								2	12	10	27	27	14	5	2		1					26.44
		Fard No. 4					2	5	18	28	19	15	7	2	1					1	1	1		23.84
		Deglet Noor R-6								3	12	28	31	22	2	2								25.71
		Canariensis No. 1			2	6	17	32	23	13	3	2		1				1						21.47
No. 3	100	Mosque							1	2	8	17	17	30	19	5	1							26.44
		Fard No. 4					2	1	8	26	32	19	5	4	1	1	1							24.03
		Government No. 1								4	9	28	33	16	9	1								25.79
		Canariensis No 1			1	1	8	18	21	24	19	7		1										22.47
		Huey							1	5	2	19	21	30	16	2								26.34
No. 4	30	Mosque										3	2	9	9	6	1							27.53
		Fard No. 4					1	3	3	8	9	3	1		1								1	23.90
		Government No. 1							1		2	4	4	7	9	1	2							26.80
		Canariensis No. 1			1	1	9	6	8	2	1	1		1										21.36
No. 5	40	Mosque								1	1	4	7	12	10	4	1							26.98
		Fard No. 4				1	1	4	7	8	7	6	3	3										23.45
		Government No. 1								1	3	6	13	12	4	1								26.20
		Canariensis No. 1				1	7	12	8	10	2													21.62
No. 6	45	Mosque								3	9	13	11	8	1									24.33
		Fard No. 4						5	4	10	11	8	7											22.75
		Government No. 1								1	5	10	16	8	3	2								24.93
		Canariensis No. 1	1	1	4	7	19	9	4															19.88
No. 7	100	Mosque									4	4	10	29	29	13	10	1						27.50
		Fard No. 4							8	24	22	35	6	3	2									24.24
		Huey						1		1	1	15	9	25	20	16	11	1						27.37
No. 8	100	Mosque							1	5	18	22	24	20	7	2	1							25.67
		Fard No. 4					6	22	35	27	9	1												22.14

TABLE 8.—*Breadths of date fruits and seeds in the 1925 experiments at Indio, Calif.*

Experiment	Number measured	Pollen used	Fruit measurements (millimeters) and frequencies									Seed* measurements (millimeters and frequencies							
			16	17	18	19	20	21	22	23	24	Mean	5	6	7	8	9	10	11	Mean
No. 1	100	Mosque		2	5	20	58	12	3			19.82			1	48	50	1		8.51
		Fard No. 4		3	11	41	36	8	1			19.38		5	64	29	1	1		7.29
		Deglet Noor R-6		10	32	41	16	1				18.66		1	42	53	4			7.60
		Canariensis No. 1	1	8	29	44	14	3	1			18.75	1	69	28	1	1			6.32
No. 2	100	Mosque			2	16	56	22	4			20.10			4	40	52	4		8.56
		Fard No. 4			6	29	52	10	3			19.75		4	53	39	4			7.43
		Deglet Noor R-6		1	9	32	47	10	1			19.59		1	40	57	2			7.60
		Canariensis No. 1		1	18	44	28	7	2			19.28	3	65	29	1	2			6.34
No. 3	100	Mosque			6	38	53	3				19.53			1	32	64	3		8.69
		Fard No. 4		8	36	46	10					18.58		1	31	61	7			7.74
		Government No. 1			17	57	25	1				19.10			4	67	29			8.25
		Canariensis No. 1		7	32	44	17					18.71	1	19	75	5				6.84
		Huey		1	11	63	23	2				19.14			6	72	22			8.16
No. 4	30	Mosque					7	7	12	3	1	21.46		1	4	12	11	2		8.30
		Fard No. 4				3	16	6	5			20.43	1	2	23	3	1			7.03
		Government No. 1					5	11	9	5		21.46		3	21	6				7.10
		Canariensis No. 1			1	3	16	6	4			20.30		3	23	3	1			7.06
No. 5	40	Mosque				8	24	7	1			20.02			2	28	9	1		8.22
		Fard No. 4			1	9	18	11	1			20.05			20	19	1			7.52
		Government No. 1				8	21	11				20.07			4	28	8			8.10
		Canariensis		1	4	17	16	2				19.53		14	26					6.65
No. 6	45	Mosque			1	10	25	9				19.93			1	8	27	8	1	9.00
		Fard No. 4			7	24	14					19.15			16	29				7.64
		Government No. 1			4	21	15	5				19.46			3	30	10	2		8.24
		Canariensis No. 1		1	14	19	11					18.88		5	34	6				7.02
No. 7	100	Mosque			2	19	59	18	1	1		20.00			6	55	37	2		8.35
		Fard No. 4		1	9	32	55	3				19.50		3	74	23				7.20
		Huey			1	1	21	48	26	6		21.12			16	67	17			8.01
No. 8	100	Mosque					21	35	28	15	1	21.40			16	72	12			7.96
		Fard No. 4			2	7	49	30	12			20.43		4	59	37				7.33

* Measured at point of greatest diameter across and at right angles to the seed furrow.

TABLE 9.—*Length of date fruits in the 1926 experiments at Indio, Calif.*

[Measurements of 30 fruits were made except where a smaller number is indicated in parentheses]

Experiment	Pollen used	Measurements (millimeters) and frequencies																						
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	Mean
No. 1	Mosque										1	5	2	12	8			2						42.0
	Fard No. 4								2	5	13	2	3	5										38.5
	Canariensis No. 2								3	5	11	6	3	2										38.2
	Deglet Noor N-12										4	4	9	8	3	1	1							41.3
	Fard FNJ-S							1			5	6	4	6	4	4								40.2
	Fard FNJ-N										2	3	7	9	6	2	1							40.8
	Menakher No. 1										1	1	6	5	8	3	4	2						41.8
	Maktum No. 5										2	6	9	6	5	2								40.4
	Deglet Noor R-6											1	6	11	4	1	4	2	1					41.8
No. 2a	Mosque												1		1	4	6	5	10	3				44.8
	Fard No. 4												4	6	7	7	3	2						42.0
	Canariensis No. 3								1	2	3	8	9	4	2	1								39.6
	Maktum No. 5												2	5	4	6	10	2		1				42.9
	Fard FNJ-S										1	2	8	1	4	8	5	1						40.8
	Fard FNJ-N												1	4	7	11	6	1						41.7
No. 2b	Deglet Noor N-10									1	2	2	6	4	5	5	4	1						41.4
	Mosque										1	1	9	1	10	5	3							41.5
	Fard No. 4										3	5	12	5	4	1								40.2
	Deglet Noor N-15												2	2	6	5	11	3	1					43.1
No. 3	Mosque											1	6	10	7		3	3						41.7
	Fard No. 4									4	5	9	7	2	3									39.2
	Canariensis No. 3							3		2	5	6	7	5	2									38.1
	Government No. 1											1	3	4	8	8	4	1	1					42.3

TABLE 9.—*Length of date fruits in the 1926 experiments at Indio, Calif.*—Contd.

Experiment	Pollen used	Measurements (millimeters) and frequencies																					Mean
		29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	
No. 4	Mosque												2	1	2	6	7	4	2	4	2			44.2
	Fard No. 4								1	1	6	7	7	3	4	1								39.6
	Canariensis No. 2						1	2	3	7	9	5	2	1										37.6
	Deglet Noor N-12								1	1		4	8	8	6	2								40.5
No. 5	Mosque										1	2	2	6	8	7	4							41.8
	Fard No. 4						1	4	5	9	8		2	1										38.0
	Saidy No. 13								1	1	3		6	11	6	2								40.7
	Deglet Noor N-18										1	3	7	9	4	5	1							41.0
No. 6	Mosque												5	9	6	5	3	2						41.9
	Fard No. 4							1	3	4	9		5	3	4	1								39.5
	Deglet Noor R-1								2	4	2		6	6	7	3								40.4
	Deglet Noor R-6										1			2	5	7	6	5	3	1				43.5
No. 7	Fard No. 4											4	6	7	8	3	1	1						41.2
	Fard FNJ-S											3	2	9	10	2	4							41.6
	Canariensis No. 2 (15).							1	1	4	5	2	1	1										37.9
	Maktum No. 5										1		4	4	10	3	3	4	1					42.3
	Maktum No. 6												3	6	8	12	1							42.1
	Maktum No. 7											1	5	4	13	2	2	3						41.9
No. 8	Mosque												2	1	5	7	10	4		1				43.3
	Fard No. 4					2	5		11	4	4	1	1	2										36.4
	Menakher No. 1													5	4	3	6	6	3	2	1			43.9
	Theory No. 20													3	3	9	8	5	2					43.5
	Saidy No. 25												1	4	8	5	8	3	1					42.9
	Fard FNJ-N										2	6	5	6	7	3	1							40.8
	Deglet Noor N-9								1			3	6	2	4	6	4	3	1					41.9
	Ascherasi										2	1	5	7	7	6	2							41.4
No. 9	Mosque												1	7	5	7	7	2		1				42.8
	Fard No. 4									1	3	5	7	3	6	4	1							40.6
	Fard FNJ-S										9	3	13	4	1									39.5
	Canariensis No. 2					1		1	2	8	9	4	4	1										37.8
	Deglet Noor N-9										1	2	4	3	7	10	3							41.8
No. 10	Ascherasi										1		5	7	8	6	3							41.7
	Deglet Noor N-9												1	7	9	13								42.1
	Theory No. 20												2		5	6	11	2	4					43.5
No. 11	Fard No. 4												2	6	6	7	6	3						42.6
	Fard FNJ-N												2	3	4	5	12	2	1	1				43.2
	Saidy No. 25															7	7	7	7	2				44.7
	Deglet Noor N-9												1	4	7	8	4	4	2					43.0
No. 12	Maktum No. 5										1	6	10	6	4	2	1							40.5
	Maktum No. 6										2	6	5	1	10	5	1							41.0
	Theory No. 20										2	1	4	5	5	8	2	1	2					42.0
No. 13 (on Deglet Noor seedling No. 6).	Mosque												2	2		7	5	2	3	3	1	3	2	44.9
	Fard No. 4									1			2	4	7	5	1	8	1	1				42.9
	Canariensis No. 2									2	1	5	10	5	3	3	1							40.3
No. 14 (on Rhars)	Mosque (15)														2		5	6	2					44.4
	Fard No.4 (7)												1		1	1	2		1	1				43.7
	Canariensis No. 2 (20).									1	1	5	7	3	3									39.9
No. 15 (on Khadrawy).	Mosque (20)			2	4	4	6	3																33.1
	Fard No. 4 (20)	4	6	6	2	2																		30.6
No. 16 (on Maktum)	Mosque (8)			3	1		2		2															33.1
	Fard No. 4 (20)			1	4	3	5	5	1	1														31.8
	Maktum No. 5 (20)			6	10	3	1																	32.0
No. 17	Mosque																2		5	8	7	6	1	46.5
	Fard RB No. 1														1		4	8	6	6	5			44.9
No. 18	Mosque															1	7	13	4	4	1			45.2
	Fard A-21-2-32											4	1	3	3	5	4	5	3	2				43.1

TABLE 10.—*Length of seeds of date fruits in the 1926 experiments at Indio, Calif.*

[Measurements of 30 fruits were made except where a smaller number is indicated in parentheses]

Experiment	Pollen used	Measurements (millimeters) and frequencies														
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Mean
No. 1	Mosque							2	7	6	8	3	2	1	1		25.6
	Fard No. 4				2	4	11	7	4		1	1					22.5
	Canariensis No. 2			5	10	7	7	1									20.6
	Deglet Noor N-12							6	12	8	2		2				24.5
	Fard FNJ-S				1	3	13	6	5	2							22.6
	Fard FNJ-N					3	7	4	10	3	1	1	1				23.5
	Menakher No. 1							5	6	11	4	3	1				24.9
	Maktum No. 5							9	10	9	1	1					24.2
	Deglet Noor R-6						1	2	6	12	7	1	1				25.0
No. 2a	Mosque							1	1	3	7	9	3	5	1		26.9
	Fard No. 4						1		8	14	5	2					24.9
	Canariensis No. 3				3	7	9	6	4	1							22.1
	Maktum No. 5						2	1	2	6	4	10	3	1	1		26.1
No. 2b	Fard FNJ-S				1	1	2	9	11	4		2					23.7
	Fard FNJ-N						1	9	11	4	3	2					24.2
	Deglet Noor N-10					2	5	5	9	6	2	1					23.7
	Mosque						1	3	8	11	4	3					24.8
	Fard No. 4					1	12	9	2	6							23.0
	Deglet Noor N-18						1	1	6	7	9	3	1	1	1		25.5
No. 3	Mosque				2	3	5	8	7	4	1						23.0
	Fard No 4						1	1	2	14		8	3	1			25.7
	Canariensis No. 3	1	1	7	9	9	1	2									20.1
	Government No. 1							1	3	12	8	6					25.5
No. 4	Mosque								1	3	8	8	5	3	2		27.0
	Fard No. 4			1		6	5	13	4	1							22.5
	Canariensis No. 2	1	2	6	9	7	3	1									20.9
	Deglet Noor N-12						4	13	8	5							23.5
No. 5	Mosque							2	3	6	7	8	2	2			26.0
	Fard No. 4			2	2	11	8	4	1	1		1					21.8
	Saidy No. 13						1	6	8	7	8						24.5
	Deglet Noor N-18							11	8	7	3	1					24.2
No. 6	Mosque								4	3	11	8	4				26.2
	Fard No.4						1	8	7	7							23.4
	Deglet Noor R-1						2	3	12	6	3	1					24.0
	Deglet Noor R-6								1	2	4	14	6	1	1	1	26.1
No. 7	Fard							6	6	10	4	2	2				23.9
	Fard FNJ-S						1	1	4	6	13	2	3				24.6
	Canariensis No. 2 (15)				1	1	2	8	2	1							21.8
	Maktum No. 5							3	5	4	8	6	4				24.7
	Maktum No. 6								5	7	5	10	1	2			25.0
	Maktum No. 7							1	7	10	3	5	4				24.5
No. 8	Mosque							2	2	4	10	6	5	1			25.2
	Fard No. 4			3	5	8		7	4	3							21.4
	Menakher No. 1							1	1	2	6	8	8		3	1	26.1
	Thoory No. 20							1	2	5	8	9	5				25.2
	Saidy No. 25								1	3	9	7	9	1			25.8
	Fard FNJ-N							2	9	6	6	6		1			24.3
	Deglet Noor N-9						1	3	1	6	5	7	4	2	1		25.1
	Ascherasi							3	3	4	9	9	1		1		24.9
No. 9	Mosque								5	5	9	5	5	1			25.1
	Fard No. 4			1		10	8	7	2	2							22.1
	Fard FNJ-S				5	7	11	4	2	1							21.8
	Canariensis No. 2	3	4	10	8	3	2										19.3
No. 10	Deglet Noor N-9					1	5	5	9	6	2	2					23.9
	Ascherasi							6	9	10	2	3					24.6
	Deglet Noor N-9							1	4	5	13	4	2	1			24.8
	Thoory No. 20						1		4	11	6	4	4				25.6
No. 11	Fard No. 4							5	9	6	7	3					24.8
	Fard FNJ-N							3	5	8	11	3					25.2
	Saidy No. 25								1	4	6	9	7	2		1	26.9
	Deglet Noor N-9								3	6	12	7	2				26.0
No. 12	Maktum No. 5					4	5	11	7	2	1						23.0
	Maktum No. 6						5	6	6	7	5	1					24.1
No. 13 (on Deglet Noor seedling No. 6).	Thoory No. 20					1	4	5	8	8	3	1					24.0
	Mosque						8	4	8	9	1						23.7
	Fard No. 4				10	7	7	4	2								21.4
	Canariensis No. 2	6	7	10	6	1											18.6
No. 14 (on Rhars)	Mosque (15)										4	2	7	2			27.4
	Fard No. 4 (7)								1	3		3					25.7
No. 15 (on Khadrawy)	Canariensis (20)				1	2	5	7	4		1						22.8
	Mosque (20)			2	8	8	2										20.5
	Fard No. 4 (20)		9	8	3												18.7
No. 16 (on Maktum)	Mosque (8)			1	2	5											20.5
	Fard No. 4 (20)	1	3	6	10												19.3
	Maktum No. 5 (20)	1	1	12	5	1											19.2
No. 17	Mosque								3	5	9	5	6	1	1		26.4
	Fard RB No.1					1	1	8	9	5	5	1					24.2
No. 18	Mosque							2		6	8	5	7	1		1	26.5
	Fard A-21-2-32					1	6	10	5	5	3						23.5

TABLE 11.—*Breadths of date fruits and seeds in the 1926 experiments at Indio, Calif.*

[Measurements of 30 fruits were made except where a smaller number is indicated in parenthesis]

Experiment	Pollen used	Fruit measurements (millimeters) and frequencies											Seed measurements (millimeters) and frequencies						
		17	18	19	20	21	22	23	24	25	26	Mean	5	6	7	8	9	10	Mean
No. 1	Mosque			4	13	11	2					20.4				21	8	1	8.3
	Fard No. 4		6	6	13	5						19.6			22	8			7.3
	Canariensis No. 2	3	12	7	5	2	1					18.8	1	15	14				6.4
	Deglet Noor N-12			9	12	6	3					20.1			16	12	2		7.5
	Fard FNJ-S		6	13	8	3						19.3		2	26	2			7.0
	Fard FNJ-N		1	8	11	7	3					20.1		3	20	5	2		7.2
	Menakher No. 1		2	4	11	9	4					20.3		1	11	15	3		7.7
	Maktum No. 5			7	11	8	4					20.3			6	20	4		7.9
	Deglet Noor R-6		2	10	10	7	1					19.8			4	20	6		8.1
No. 2a	Mosque				6	13	11					21.2				13	17		8.6
	Fard No. 4			1	9	14	6					20.8			21	9			7.3
	Canariensis No. 3	1	5	4	10	8	2					19.8		16	13	1			6.5
	Maktum No. 5			2	11	7	9	1				20.9			9	19	2		7.8
	Fard FNJ-S		1	7	19	3						19.8			16	14			7.5
	Fard FNJ-N			1	12	10	7					20.8		3	21	6			7.1
No. 2b	Deglet Noor N-10			8	12	8	2					20.1		1	25	4			7.1
	Mosque			3	12	10	5					20.6				15	15		8.5
	Fard No. 4			4	15	11						20.2		4	24	2			6.9
	Deglet Noor N-18		1		9	10	10					20.9		1	14	14	1		7.5
No. 3	Mosque		10	10	9	1						19.0			1	17	12		8.4
	Fard No. 4	2	14	12	2							18.5		1	11	18			7.6
	Canariensis No. 3	12	12	4	2							17.9	1	21	7	1			6.3
	Government No. 1		1	8	20	1						19.7			2	20	8		8.2
No. 4	Mosque			1	3	7	12	4	3			21.8			1	11	17	1	8.6
	Fard No. 4		1	2	11	7	9					20.7		2	16	12			7.3
	Canariensis No. 2		2	7	14	6	1					19.9		12	18				6.6
	Deglet Noor N-12			2	15	9	4					20.5			26	3	1		7.2
No. 5	Mosque			3	13	9	3	2				20.6			2	21	7		8.2
	Fard No. 4		2	5	15	7	1					20.0		1	18	11			7.3
	Saidy No. 13		2	7	11	5	5					20.1		1	3	23	3		7.9
	Deglet Noor N-18		2	8	14	6						19.8			12	17	1		7.6
No. 6	Mosque		1	2	18	9						20.2			1	22	7		8.2
	Fard No. 4		1	3	14	10	2					20.3			15	15			7.5
	Deglet Noor R-1			2	14	10	3	1				20.6			6	21	3		7.9
	Deglet Noor R-6		1	11	11	7						19.8			5	21	4		8.0
No. 7	Fard No. 4				7	13	10					21.1			25	4	1		7.2
	Fard FNJ-S				2	9	14	5				21.7			18	11	1		7.4
	Canariensis No. 2 (15)			4	4	3	4					20.5	1	4	9	1			6.7
	Maktum No. 5			2	6	14	7	1				21.0			10	17	3		7.7
	Maktum No. 6			3	3	16	4	4				21.1			12	18			7.6
	Maktum No. 7				10	9	9	2				21.1			4	24	2		7.9
No. 8	Mosque			1	5	10	8	6				21.4			5	18	7		8.1
	Fard No. 4			3	16	9	2					20.3		2	20	7	1		7.2
	Menakher No. 1				2	1	9	12	5	1		22.7			2	21	7		8.2
	Thoory No. 20					5	11	13	1			22.3			4	21	4	1	8.1
	Saidy No. 25				3	9	14	2	1	1		21.7			8	18	3	1	7.9
	Fard FNJ-N				6	11	10	3				21.3			11	18	1		7.7
	Deglet Noor N-9			1	3	12	8	6				21.5			7	20	3		7.9
	Ascherasi				3	10	16	1				21.5			5	23	2		7.9
No. 9	Mosque		1	7	14	6	2					20.0			1	17	12		8.4
	Fard No. 4	1	5	8	12	4						19.4		3	18	9			7.2
	Fard FNJ-S		4	16	9	1						19.2			19	11			7.4
	Canariensis No. 2	3	12	13	2							18.5		13	17				6.6
	Deglet Noor N-9		3	19	6	2						19.2			10	19	1		7.7
No. 10	Ascherasi			1	9	14	6					20.8			3	24	3		8.0
	Deglet Noor N-9			1	9	11	8	1				21.0			8	22			7.7
	Thoory No. 20			1	2	12	14	1				21.4			2	25	3		8.0
	Fard No. 4			1	5	14	10					21.1			24	6			7.2
No. 11	Fard FNJ-N				4	13	12	1				21.3			22	8			7.3
	Saidy No. 25				2	7	14	7				21.8			1	23	6		8.2
	Deglet Noor N-9				3	9	15	3				21.6			4	25	1		7.9
No. 12	Maktum No. 5			2	12	12	4					20.6			1	24	5		8.1
	Maktum No. 6		1	6	16	6	1					20.0			4	24	2		7.9
	Thoory No. 20			2	12	12	4					20.6			5	24	1		7.9
No. 13 (on Deglet Noor seedling No. 6).	Mosque				6	9	13	2				21.4			14	14	2		7.6
	Fard No. 4			4	10	12	4					20.5		4	24	2			6.9
	Canariensis No. 2		3	5	15	6	1					19.9		21	9				6.3
No. 14 (on Rhars).	Mosque (15)				4	5	5	1				21.2				10	5		8.3
	Fard No. 4 (7)			1	2		4					21.0			2	5			7.7
	Canariensis No. 2 (20)		1	2	13	3	1					20.1		1	13	6			7.3

TABLE 11.—*Breadths of date fruits and seeds in the 1926 experiments at Indio, Calif.*—Continued

Experiment	Pollen used	Fruit measurements (millimeters) and frequencies										Seed measurements (millimeters) and frequencies						
		17	18	19	20	21	22	23	24	25	26	Mean	5	6	7	8	9	10	Mean
No. 15 (on Khadrawy).	Mosque (20)				2	2	11	4	1			22.0				9	11		8.6
	Fard No. 4 (20)			2	5	9	4					20.8			4	16			7.8
No. 16 (on Maktum).	Mosque (8)								6		2	24.5			1	6	1		8.0
	Fard No. 4 (20)					1	7	11	1			22.6			10	10			7.5
	Maktum No. 5 (20).						9	7	4			22.8			8	12			7.6
No. 17	Mosque			1	6	12	10	1				21.1				13	16	1	8.6
	Fard RB No. 1			8	13	6	3					20.1			16	14			7.5
No. 18	Mosque			1	9	12	7	1				20.9			2	14	14		8.4
	Fard A-21-2-32			6	15	7	2					20.2		2	17	11			7.3

In every experiment the pollen from Mosque produced larger fruit (fig. 6, D) and seed (fig. 5, B, and 7) than that from Fard No. 4. Since for these two pollens the breadths showed a tendency to vary in the same direction, the lengths afford the best basis for comparison. In all but one of the seven experiments on Deglet Noor in 1925 the mean difference of fruit lengths was more than three times its probable error,[5] the least significant difference in six of the experiments being 1.6 ± 0.16 mm. in experiment 2 (100 measurements). The mean difference of seed lengths was significant in every one of the seven, the least being 1.5 ± 0.28 mm. in experiment 6 (45 measurements). Considering each mean as a unit, the average mean difference[6] for these seven experiments was 2.2 ± 0.3 mm. for the fruit and 3.1 ± 0.25 mm. for the seed.

TABLE 12.—*Average of 10 measurements of fruits and seeds in the 1926 experiments in the Salt River Valley, Ariz.*

Experiments 1-7 were at the Tempe Date Garden, and experiments 8 and 9 were at the garden of the Arizona Orchards Company]

Experiment	Pollen used	Fruits		Seeds	
		Length	Breadth	Length	Breadth
No. 1	Mosque	42.1	21.1	25.1	8.5
	Fard	39.1	19.6	22.5	7.6
No. 2	Mosque	42.4	23.9	25.3	8.1
	Fard	39.0	21.0	22.2	7.4
No. 3	Mosque	42.4	21.2	24.9	8.4
	Fard	39.7	20.0	21.7	7.4
No. 4	Mosque	43.8	22.7	26.4	8.3
	Fard	40.6	20.0	22.5	7.1
	Fard FNJ-S	41.4	21.4	24.1	7.4
	Fard FNJ-N	41.5	21.3	22.8	7.3
No. 5	Mosque	42.9	21.6	24.6	8.8
	Fard	39.3	20.0	20.9	7.3
	Fard FNJ-S	40.8	20.9	21.4	7.4
	Fard FNJ-N	40.8	20.8	22.3	7.6
No. 6	Mosque	42.6	21.4	25.1	8.1
	Fard	40.0	20.4	22.5	7.3
	Fard FNJ-S	40.0	20.4	22.5	7.2
No. 7	Mosque	40.2	19.4	23.1	7.7
	Fard	38.8	19.3	21.9	7.9
No. 8	Mosque	43.2	23.6	26.4	9.4
	Fard	42.4	22.1	23.4	8.0
No. 9 (Iteema)	Mosque	43.8	24.0	26.9	10.1
	Fard	41.0	22.5	23.5	8.6

[5] For the probable error of the mean the formula used is $PE = 0.6745 \sqrt{\frac{\Sigma v^2}{n(n-1)}}$

[6] PEARSON, K. ON THE PROBABLE ERROR OF A COEFFICIENT OF MEAN SQUARE CONTINGENCY. Biometrika 10: 570-573. 1915.

All of the 1926 experiments on Deglet Noor at the Indio station showed a significant mean difference between the Mosque and the Fard No. 4 pollinations, the least for the fruit being 1.3 ± 0.21 mm.

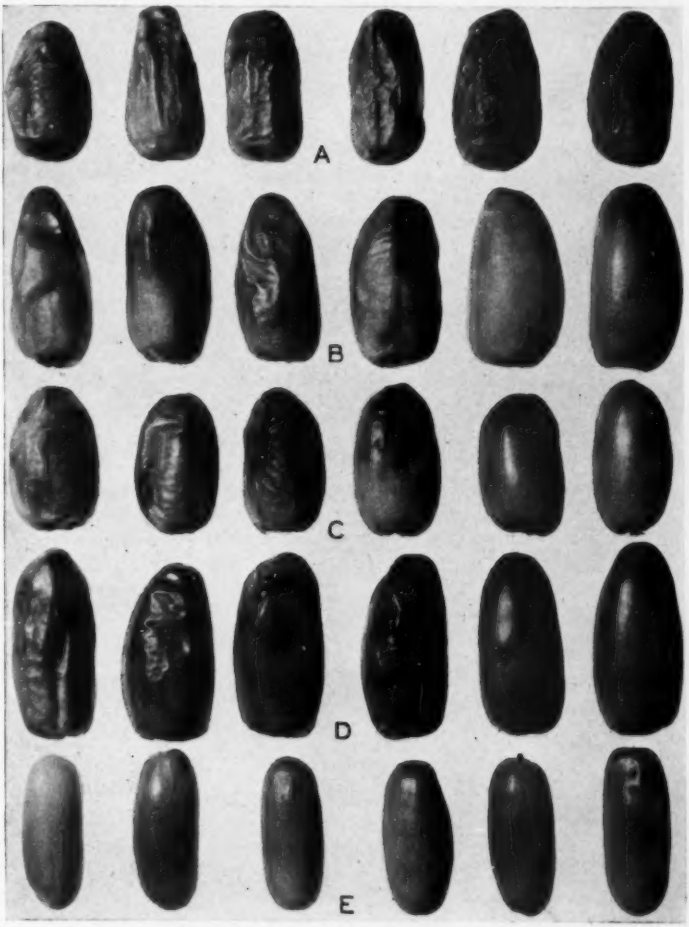

FIG. 6.—Typical dates of the Deglet Noor variety produced by different pollens on the same cluster in experiment 4 in 1925. The male palms represented are: A, Fard No. 4; B, Government No. 1; C, Canariensis No. 1; D, Mosque; and E, unpollinated dates. The dates from Fard No. 4 pollen were all full ripe on September 11, when the photograph was taken, but there were still immatre dates on all the other strands

and for the seed, 1.8 ± 0.21 mm. The average mean for nine experiments was 3.4 ± 0.39 mm. for the fruit and 3.1 ± 0.21 mm. for the seed.

In the Salt River Valley experiments in 1926 ten measurements were made in each pollination. (Table 12.) These measurements were comparable to the larger number made at Indio, the average mean difference in length for eight experiments with Mosque and

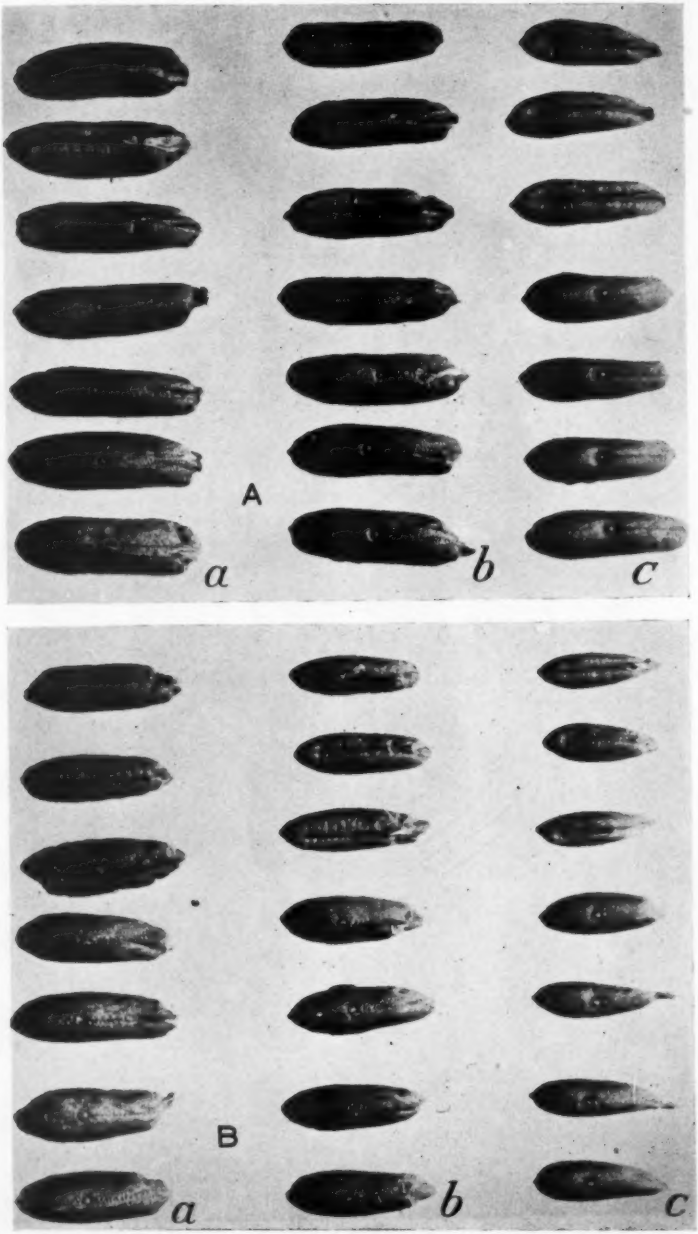

FIG. 7.—A.—Typical Rhars seeds produced on the same cluster by different pollens in experiment 14 in 1926. The male palms represented are: *a*, Mosque; *b*, Fard No. 4; and *c*, Canariensis No. 2. B.—Typical seeds from Deglet Noor seedling No. 6 produced on the same cluster by different pollens in experiment 13 in 1926. The male palms represented are: *a*, Mosque; *b*, Fard; and *c*, Canariensis No. 2

Fard No. 4 on Deglet Noor being 2.6 ± 0.25 mm. for the fruit and 2.9 ± 0.21 mm.for the seed.

That this increase in size is accompanied by an increase in weight is indicated by the results of determinations in nine experiments with Deglet Noor at Indio in 1926. The mean weight of the seed was 102 gm. per 100 for the pollinations with Mosque and 68.3 gm. per 100 for the pollinations with Fard No. 4, a difference of 33.7 ± 1.85 gm., or 49.3 per cent. For the fruit the mean dry weight of flesh only was 725.1 gm. per 100 for pollinations with Mosque and 623.2 gm. per 100 for the pollinations with Fard No. 4, a difference of 101.9 ± 21.54 gm., or 16.4 per cent. In the weights, as in the measurements, it is apparent that the effect on the flesh is proportionately smaller and more variable than on the seed. By way of comparison, the seed in four experiments with pollen of *Phoenix canariensis* averaged 45.1 gm. per 100, while the dry weight of flesh only in three experiments averaged 602.8 gm. per 100.

It seems more than likely that these pollens will affect the fruit of other varieties in a similar manner. The results of two seasons' experiments with Deglet Noor seedling No. 6 and of a preliminary test with each of the varieties Rhars, Khadrawy, Maktum, and Iteema in 1926, included with the other tabulations, are entirely in harmony with the results obtained with the Deglet Noor variety.

DIFFERENCES IN QUALITY

So far no differences in the fruit as regards texture, flavor, etc., have been found to appear consistently in all of the experiments. This applies to all of the pollens tested. Through the courtesy of A. F. Sievers, of the Bureau of Plant Industry, United States Department of Agriculture, sugar analyses were made of the fruit in one experiment in 1925 with pollens from five male palms represented including Mosque, Fard No. 4, and Canariensis No. 1, and in two experiments in 1926, Mosque and Fard No. 4 being represented in both and Canariensis No. 2 in one. As all of the samples had been stored for some weeks before they were sent to the laboratory, the effect of storage may be questioned, but the results of the analyses did not indicate any significant differences in the sugar content. The likelihood that pollen has any direct effect on the sugar of the date would seem to be lessened by the fact that the sugar content of two samples of "unpollinated dates," one in 1925 and one in 1926, which finally ripened about three months after those which received pollen, varied less than 2 per cent from that of the nearest pollinated fruit.

Except in so far as the size and proportions of the seeds and fruits may be involved, the evidence in hand does not indicate any direct effect of pollen on the fruit which would properly come within the scope of the rather indefinite term "quality." But there is an indirect influence. In the Coachella Valley, Calif., it is a matter of common observation among date growers that Deglet Noor dates ripening very early in the extreme heat of late summer show a distinct tendency to be inferior in quality to the fruit which ripens later in the season when the weather is cooler. Perhaps the reverse may occur in other localities where climatic conditions are frequently unfavorable during the latter part of the ripening season. In either case, pollen by varying the time of ripening of the fruit might indirectly affect the quality

of a large proportion of the crop. Furthermore, it should be noted that differences in the time of ripening due to pollen may be at any season indirectly responsible for apparent differences in texture by causing one set of fruit to mature during a period of lower humidity than another. Hence, from a small number of experiments it might appear that one pollen was actually producing a softer date than another, whereas the results under other conditions with reverse fluctuations of relative humidity would be exactly the opposite.

In the seeds, the chief difference other than size produced by pollen was in the color. While the range was such that an individual seed could not have been identified with certainty on that basis, it was apparent in every experiment on Deglet Noor that the seeds resulting from pollinations with Mosque were lighter than those from pollinations with Fard No. 4, the former ranging from light drab (R. XLVI) to wood brown (R. XL), while the latter ranged from wood brown (R. XL) to snuff brown (R. XXIX). Seeds from pollen of *Phoenix canariensis* were even darker, verona brown (R. XXIX) being the prevailing shade. The peculiar tapering base produced by pollen of *P. canariensis* on the seeds of Deglet Noor fruit has already been mentioned. This tapering tendency in a lesser degree also occurred in the pollinations with *canariensis* on Rhars and Deglet Noor seedling No. 6.

OTHER MALE PALMS TESTED

If it were only by some fortunate accident that Mosque and Fard No. 4 proved to be so diverse and no other males could be shown to vary in such proportion, the immediate practical value of these experiments would be of somewhat less consequence, for the hope of the future would be largely dependent on breeding through a long period of years. However, it is now clear that there are *dactylifera* males equally as late as Mosque and others equally as early as Fard No. 4.

As mentioned above, from one to four preliminary tests were made at the Indio station with pollen from each of 20 other palms of *Phoenix dactylifera* and three of *P. canariensis*. Most of the *dactylifera* males ranged between Mosque and Fard No. 4, and, as might be expected from the nature of ripening there were many minor fluctuations. Yet at least five (Fard FNJ–S, Fard FNJ–N, Fard RB No. 1, Fard A–21–2–32, and Deglet Noor N–12, two of which are shown in Figure 3) appeared comparable to Fard No. 4 and three (Deglet Noor R–6, Deglet Noor N–9, and Huey, the last being designated by the name of the owner of the palm located near Bard, Calif.) to Mosque. It will be noted that of the male palms producing early-ripening fruits four of the five just mentioned are seedlings of the Fard variety. One of these (Fard FNJ–N) showed a tendency to ripen fruit even earlier than Fard No. 4. Whether any corresponding uniformity may occur among the seedling males of other varieties is for future tests to determine, but in these preliminary tests it did not occur among the several seedling males of the Deglet Noor variety, one of which was comparable to Fard No. 4 and two about on a par with Mosque.

The results of these preliminary tests will of course be subject to further verification, but from the consistent behavior of the pollens of Mosque and Fard No. 4 in every test during a period of two years

such verification may be expected to be largely a determination of the exact lateness or earliness of ripening produced. In other words, because of the range of experimental error a small number of tests may not indicate with certainty whether one pollen is a trifle later than Mosque or another a trifle earlier than Fard No. 4, yet there can be little doubt even from a few careful experiments that the one is definitely a late pollen and the other definitely an early one.

So far no exact correlation between size and earliness of fruit has been found. Yet this much is apparent, that among the male palms of *Phoenix dactylifera* no early pollens produced very large fruits or seeds and no late pollens produced very small fruits or seeds.

On the other hand, the smallest fruits and seeds produced in any of these tests were from the pollen of *Phoenix canariensis*. Pollens from two palms of this species, Nos. 1 and 2, ripened the fruit even later than the Mosque, while the third, No. 3, ripened the fruit somewhat earlier.

It seems very questionable whether the limits of variation have yet been reached. On the contrary, the diversity among the few already tested makes it more than likely that among the hundreds of males scattered wherever palms are grown there are many which will produce, and are producing, variations as great as or greater than those that appeared in any of these experiments.

SUMMARY

To test the direct effect of pollen on the fruit of the date palm, experiments were made at the United States Experiment Date Garden at Indio, Calif., in 1925 and 1926,[7] with additional tests in the Salt River Valley, Ariz., in 1926. Pollens from 25 staminate palms, 22 seedlings of *Phoenix dactylifera*, and 3 of *P. canariensis* were used on pistillate palms of the Deglet Noor variety. In some of the experiments successive inflorescences were pollinated, each with a different pollen. In most of them several pollens were applied, each to a different set of strands on the same inflorescence. Including two tests on a Deglet Noor seedling palm and one each on the Rhars, Khadrawy, Iteema, and Maktum varieties, two of the pollens which produced diverse effects were directly compared in 30 experiments. The resulting fruit and seed showed consistent differences according to the source of the pollen.

Significant differences were produced in the size and proportions of the seed.

Pollen from *Phoenix canariensis* affected the shape of the seed by producing a distinct, tapering base.

Variations in the size of the seed were accompanied by differences in the size of the fruit itself, though the latter were proportionately less than the former.

The most striking effect of pollen was a difference in the time of ripening of the fruit, which in some of the experiments was as much as 10 days in the early part of the season, with a tendency to increase in the latter part of the season.

[7] A still more extensive series of pollination experiments was conducted in 1927. The data, as far as they have been assembled and studied prior to the publication of this article, completely verify the results obtained in 1925 and 1926.

Xenia, known to occur in corn, wheat, and many other plants, may be the explanation of the direct effect of pollen on the seed, but it does not account for the influence on the fruit outside the embryo and endosperm. The data suggest an interrelation,[8] heretofore unrecognized, between the embryo and endosperm and the tissues outside.

These experiments indicate the importance of a further study of the pollination problems involved in date culture, but they are of immediate significance to date growers, emphasizing the need for careful selection of male palms. It is evident that pollen may be utilized as a factor in obtaining high-grade standardized fruit, and through its influence on the time of ripening it may be a means of adapting date culture to minor climatic variations.

[8] For the direct effect of pollen on the tissues of the mother plant outside the embryo and endosperm, Walter T. Swingle, under whose direction the experiments herein reported were initiated, has proposed the term "metaxenia," first in a report and discussion of the evidence at the meeting of the Southwestern Division of the American Association for the Advancement of Science at Phoenix, Ariz., Feb 15–18, 1926. Later a more complete discussion was presented in two papers read by Swingle before the International Congress of Plant Sciences at Ithaca, N. Y., August 16–23, 1926, under the following titles, abstracts of which appear in the proceedings of the congress: SWINGLE, W. T. HYPOTHETICAL EXPLANATION OF METAXENIA OR EFFECTS EXERTED BY THE MALE PARENT ON TISSUES OF THE MOTHER PLANT LYING OUTSIDE OF THE EMBRYO AND ENDOSPERM. [Unpublished manuscript.]

—— and NIXON, R W. THE EFFECTS EXERTED BY DIFFERENT POLLENS ON THE DEVELOPMENT OF THE FRUIT OF THE DATE PALM. [Unpublished manuscript.]

DETERMINATION OF LENGTH OF TIME DURING WHICH THE FLOWERS OF THE DATE PALM REMAIN RECEPTIVE TO FERTILIZATION[1]

By A. R. LEDING

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INTRODUCTION

Few experiments have been made and little published on the length of time after the opening of the flower spathe during which the pistillate flowers of the date palm (*Phoenix dactylifera*) remain receptive to fertilization by pollen from the staminate flowers. It has been believed that high percentages of fertilization may be obtained as long as two weeks after the opening of the flowers. Drummond [2] stated that pollinations up to the eleventh day after opening gave 98 per cent of fruit setting on the Deglet Noor variety, 50 per cent on Saidy, and about 25 per cent on Thoory. It is the recollection of the writer, who was identified with those experiments, that the control of chance pollination from outside sources was inadequate in the light of the results of the series of tests herein described.

In order to obtain more conclusive evidence, a series of experiments covering a period of four years (from 1923 to 1926) was carried on at the United States field station at Sacaton, Ariz., where date palms have been successfully grown and fruit produced for a number of years.

METHODS

In the course of these experiments a method of protecting the female flowers from chance pollination was worked out. After the spathes had reached nearly their maximum size, but before they had begun to open, they were covered with transparent bags made of two layers of waxed paper of medium weight. The bags were carefully made by hand to fit the spathes rather closely and were air-tight except at the open end. When drawn down over the spathes they were tied tightly and protected with a thick layer of absorbent cotton to prevent the entrance of insects and to reduce the possibility of the entrance of wind-blown pollen. (Fig. 1.) In the experiments of 1924, 1925, and 1926, in addition to being bagged, the spathes were carefully washed with grain alcohol applied with a camel's hair brush. After this treatment the chance of wind-blown viable pollen remaining on the spathes was extremely remote. That the protection from extraneous pollination afforded by these measures was good has been evidenced by clusters which were allowed to remain covered for several weeks upon which no fertilized fruits whatever were found. After the bagging of the spathes they were kept under observation from day to day and the date of opening duly noted.

[1] Received for publication Aug. 29, 1927; issued March, 1928.

[2] DRUMMOND, B. PROPAGATION AND CULTURE OF THE DATE PALM. U. S. Dept. Agr. Farmers' Bul. 1016: 21–22. 1919.

FIG. 1.—Bagged spathes on seedling date palm, showing method of application of transparent paper bags

At intervals varying from 1 to 33 days after the opening of the spathes the bags were removed and pollination performed. Pollen collected from the same male palm was always used as far as possible each season, and in no case was more than one kind of pollen applied on the same tree. Tufts of sterile absorbent cotton heavily covered with the pollen were applied to each flower cluster and tied in place, the quantity of pollen thus brought into proximity to the flowers being considerably greater than if twigs of male blossoms had been used. The method of applying the pollen was the same in all cases.

EXPERIMENTAL DATA

EXPERIMENTS IN 1923

In the 1923 experiments 46 clusters on 8 palms were pollinated after periods of delay up to 11 days after the opening of the spathes. Three clusters were pollinated immediately after opening. Greater stress was laid on the periods of delay of 4 to 9 days, as it was believed that during this period the changes in the condition of the flowers might be most apparent. The results of these experiments are given in Table 1, in which the results from all the trees are combined, grouped according to the number of days that pollination was delayed, and averaged according to the number of clusters in each group. It will be noted from this table that after the first figures, which represent the results when pollen was applied as soon as the spathes opened, there is a gradual decrease in the percentage of fertilized flowers as the delay in application of pollen was lengthened, with the exception of the seventh day, when there was a slight increase which was not significant. The highest single percentage attained was 89.6 on a cluster pollinated immediately after opening, and the lowest was 7.2 on a cluster delayed 11 days, the limit of the delay in this group of experiments.[3]

TABLE 1.—*Percentage of date flowers fertilized in delayed-pollination experiments, Sacaton, Ariz., 1923*

Period of delay	Number of clusters pollinated	Percentage of flowers fertilized	Period of delay	Number of clusters pollinated	Percentage of flowers fertilized
0 day	3	73.6	7 days	5	59.2
2 days	1	89.0	8 days	7	46.0
3 days	1	83.0	9 days	6	35.3
4 days	6	70.0	10 days	4	26.3
5 days	6	65.7	11 days	2	23.2
6 days	5	54.3			

EXPERIMENTS IN 1924

In the 1924 experiments the period of delay was extended to 14 days, and two clusters were pollinated in each period. Table 2 gives the results of these experiments. In this table it will be noted that there are some fluctuations in the figures, but the general trend of the average percentage of fertilized flowers is downward as the delay

[3] The results of these tests in 1923 were reported in the following circular: KING, C. J., and LEDING, A. R. AGRICULTURAL INVESTIGATIONS AT THE UNITED STATES FIELD STATION, SACATON, ARIZ., 1922, 1923, AND 1924. U. S. Dept. Agr. Circ. 372: 37–38. 1926.

increases. The percentage of flowers fertilized even in the periods of little or no delay is rather low, but it was true of this season that all of the pollinations made among the group of seedling palms of which those in the test were members were less effective than in most years.

TABLE 2.—*Percentage of date flowers fertilized in delayed-pollination experiments, Sacaton, Ariz., 1924*

Period of delay	Percentage of flowers fertilized	Period of delay	Percentage of flowers fertilized	Period of delay	Percentage of flowers fertilized
0 day	67.0	5 days	56.5	10 days	40.3
1 day	68.4	6 days	33.9	11 days	27.5
2 days	42.0	7 days	49.9	12 days	20.6
3 days	64.0	8 days	43.0	13 days	29.5
4 days	53.8	9 days	42.1	14 days	15.7

EXPERIMENTS IN 1925

In the 1925 experiments seven seedling palms were employed, but owing to the fact that on four some of the bags pulled loose from their bottom wrapping of cotton or were accidentally injured, the results from only three were taken into consideration. In these experiments the intervals between the delay periods were increased to five days instead of continuing with the one-day interval as in the two previous years. Table 3 gives the results of this group of experiments.

TABLE 3.—*Percentage of date flowers fertilized in delayed-pollination experiments, Sacaton, Ariz., 1925*

Palm No.	Period of delay (days)	Percentage of flowers fertilized
A-16	0	70.1
	4	67.7
	10	21.0
A-24	0	57.0
	5	48.3
	10	33.2
	15	7.3
A-25	1	78.8
	10	1.4
	15	.9

In this connection it is significant that in an experiment on the use of year-old pollen during the same season, where the paper bags sustained storm injury, the fewest fertilizations occurred on the cluster which opened 16 days before the bag was torn. This supports the theory that these fertilizations resulted from wind-blown fresh pollen and shows clearly that at 16 days after the opening of the spathe there were but few flowers still capable of being fertilized.

EXPERIMENTS IN 1926

In 1926, owing to the writer's transfer to another station, the investigations were necessarily of a very limited character. It was possible to work on only two clusters on a full-grown, well-isolated palm of the Deglet Noor variety. Pollen for this test was sent by mail from

the United States Experiment Date Garden at Indio, Calif., and came from two registered male palms. On receipt the pollen was shaken from the flowers and placed in glass jars by an assistant, the writer not coming into contact with it prior to the time it was applied to the flowers.

These experiments were conducted in a manner entirely different from those of previous years. Immediately after the rupture of the spathes they were opened and the blossoms bagged as quickly as possible. Instead, however, of inclosing the entire cluster in one bag, the threads were divided into groups of four, each group being covered with a narrow, double-thickness bag of oiled paper with a layer of cotton around the bottom of each bag, as in previous years. At the time these operations were carried on, no male palms were in bloom at any point in the vicinity, and the writer had been scrupulously careful not to come into contact with the pollen received by mail or any carried over from the year before. In addition to the bagged groups of threads, of which there were six on each cluster, one group of four was hand pollinated at once, but only after the other groups had been securely bagged. The pollen was applied by means of a small tuft of absorbent cotton, plentifully covered, and each blossom was touched in the process. The tuft of cotton was afterwards tied among the threads, which were then left uncovered. The applications of pollen were spaced at 4-day intervals up to 20 and 16 days on the two clusters respectively, after which longer intervals were allowed. After each group was pollinated, the bag was left off and no further attention given it.[4]

The results obtained in these experiments are given in Table 4. It will be noted that the percentage of fertilized flowers even on the groups of immediate pollination and those of the shorter delays was rather low. The reason for these low percentages is probably closely connected with the weather conditions at the time. During the earlier part of the experiments the weather was far from ideal for date pollination. Considerable cloudy weather with frequent showers occurred during the first 10 days, and this was undoubtedly the principal factor in the low percentages of fertilization. This is clearly indicated in the pollination which was made on March 9 on cluster A, 8 days after the opening of the spathe. On this day and the one following the weather was cloudy most of the time, with frequent showers of rain. At the time of the next pollination, March 13, more favorable conditions prevailed, and though the delay was 4 days greater, over 9 per cent more fertilizations occurred. Similarly, on cluster B, on the same date (March 9), a slightly lower percentage of fertilization occurred than on March 13 and 17, 4 and 8 days later, respectively, when weather conditions were more favorable.

That the weather is a factor influencing successful date pollination is of course well known among date growers, and these instances are cited here merely to indicate the probable cause of the low percentages which occurred at the beginning of the experiment when higher ones might have been expected.

[4] The writer is indebted to Harold Fulton, of the Office of Cotton, Rubber, and Other Tropical Plants, Bureau of Plant Industry, for assistance in handling pollen and making pollinations in his absence on Mar. 9.

TABLE 4.—*Percentage of date flowers fertilized in delayed-pollination experiment, Sacaton, Ariz., 1926*

Dat pollinated	Period of delay (days)	Number fertilized	Number unfertilized	Percentage of flowers fertilized
Cluster A:				
Mar. 1	0	126	156	44.68
Mar. 5	4	123	116	51.46
Mar. 9	8	111	189	37.00
Mar. 13	12	134	157	46.05
Mar. 17	16	65	212	23.46
Mar. 21	20	71	223	24.15
Mar. 30	29	24	235	9.27
Cluster B:				
Mar. 5	0	123	207	37.27
Mar. 9	4	142	203	41.16
Mar. 13	8	132	188	41.25
Mar. 17	12	146	198	42.44
Mar. 21	16	136	207	39.65
Mar. 30	25	66	271	19.58
Apr. 7	33	35	269	11.51

DISCUSSION

While there has been some fluctuation in the percentages of fertilized flowers in these experiments, and a high percentage has seldom been obtained even where pollination was prompt, it must be borne in mind that during the first three years the work was carried on in a planting of about 200 seedling palms, no two of which were alike in character or behavior. A certain part of the variation which is found in the figures is no doubt due to the physiological differences in the plants and would not have been so evident had the work been possible on a number of palms of the same variety. There is some evidence, not as yet subjected to rigid experimental test, that in the case of a few date varieties similar physiological differences exist, limiting the time of delayed pollination. As has been explained, weather conditions had considerable bearing on the results of the 1926 experiment.

CONCLUSIONS

On the whole the results obtained in these experiments clearly indicate that the longer pollination is delayed after the opening of the spathe the fewer fertilizations will be effected, and that when the object to be desired is a heavy setting of fruit it is unwise to delay pollination more than a few days. That high percentages of fertilized flowers may be obtained after pollen has been withheld for periods of 10 days or more is definitely controverted by the results of the work herein reported.

DISPERSAL OF THE COTTON-BOLL WEEVIL, ANTHONOMUS GRANDIS BOH.[1]

By F. A. FENTON, *Entomologist*, and E. W. DUNNAM, *Assistant Entomologist, Cotton Insect Investigations, Bureau of Entomology, United States Department of Agriculture*[2]

INTRODUCTION

Many flying insects have definite periods during the year when they leave their breeding grounds and disperse to other places by means of flight. The cotton-boll weevil is no exception. Although rather sluggish at certain times of the year and rarely using its wings, this species during the midsummer months becomes restless and flies readily from field to field in what is popularly termed the "migration." Prior to this time the adult, when disturbed, folds its legs beneath its body and often drops from the plant, feigning death or "sulling." These insects act altogether differently during the flight period. They are alert, and upon the slightest disturbance usually take to flight.

This phase of weevil behavior was studied during 1924 and 1925 as a part of an investigation of the biology of this pest at Florence, S. C. This paper deals primarily with the above-mentioned general summer-flight period of the species, and not with the less extensive dispersal habit of the female weevil after she becomes sexually mature.

HISTORICAL

The fact that the boll weevil has a summer dispersal period during which it flies considerable distances was first discovered by H. A. Morgan in 1904. Hunter and Hinds (*5*)[3] discussed this fact, stating that on the Louisiana line, where this species was advancing, several distinct movements were observed. They noted that the flights began soon after the period of maximum infestation was reached. Newell (*8*) stated that this was induced or accelerated by an insufficiency of uninfested squares. He observed that the dispersal was not a daily continuous movement but that marked distinct migrations occurred several days apart. Hinds and Yothers (*3*) noted that the most extensive flights came between August 15 and September 20, when the cotton plant had practically ceased to form squares and there was no food available. Hunter (*4*) wrote that this movement took place frequently when fields were only slightly infested, stating that "the insect has a well-developed instinct for extending its range into new territory." He also observed that it did not fly in any particular direction unless governed by the wind and that "if there is no wind or only a light one, a weevil is as likely to fly in one direction as in another." Hunter and Pierce (*6*) divided natural dissemination as follows: (*a*) Spring search for cotton, quoting A. C. Morgan's findings at Victoria, Tex., that the fed male could fly as far as 775

[1] Received for publication Apr. 13, 1927; issued March, 1928.

[2] The writers are indebted to E. C. Bolt and A. M. Woodside, temporary assistants, for carrying out various details of the investigation here reported.

[3] Reference is made by number (italic) to "Literature cited," p. 149.

yards, the fed female 350, the average being 63.5, as compared with 66.6 yards for unfed weevils; (*b*) spring spread within the fields, when the insect travels at an average rate of 0.35 foot per day; (*c*) summer flights; (*d*) fall dispersion, this being due to a scarcity of food and breeding places because of maximum infestation, and also to an instinct to invade new territory; and (*e*) hibernation flight, which began before a lowering of the temperature. Hinds (*1*) found that in the spring for more than six weeks the adults had not moved more than 50 yards from the point at which they started and concluded that the field-to-field movement did not take place so long as uninfested squares continued abundant. Finally, Hinds and Bradley (*2*) stated that this migration was coincident with the occurrence of considerable numbers of weevils in the blooms.[4]

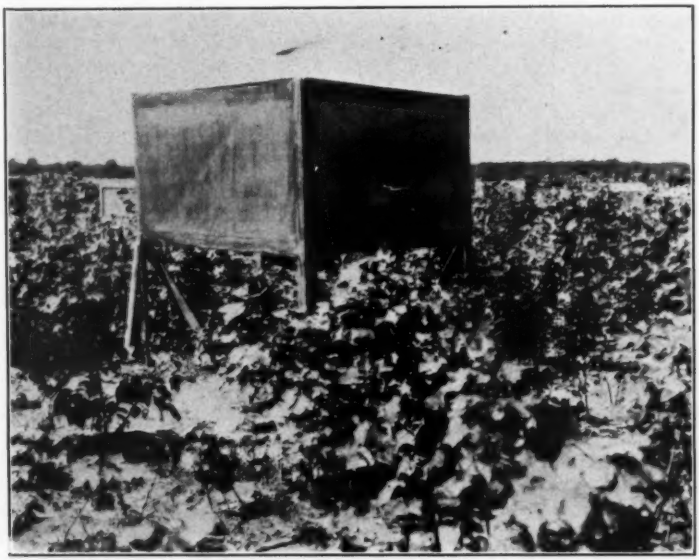

FIG. 1.—Screen trap used in studies of boll-weevil dispersal

METHODS

In order to determine when weevils were actually flying about, a number of screen traps were set up in or near cotton fields. (Fig. 1.) Each trap was made by tacking a piece of ordinary window screening 10 by 3 feet to three stout pieces of wood about 8 feet long, one at each end and one in the middle of the wire. Three holes were dug in the ground in a triangular arrangement to receive the supports of the screen, so that when the latter was in place the two wings formed a right angle and the lower margin was about 3 feet above the surface of the ground. The whole structure was securely braced so that the wire was taut. The screening was then thickly coated with a commercial sticky tree-banding preparation. This in turn was bordered

[4] Since this manuscript was written, an important paper on early summer dispersion of the boll weevil has been published by Dwight Isely (7).

with a heavy creosote mixture commonly used in banding trees as a protection against gipsy-moth caterpillars. The latter precaution was found to be necessary to prevent weevils from escaping on hot days when the commercial preparation often failed to hold them. These traps were examined twice daily and all weevils removed and counted.

DISPERSAL IN 1924

The first trial screen trap was under observation in 1924. This was set up July 29 in the center of a cotton field, and the first weevil was captured on it August 7. From this date up to November 14

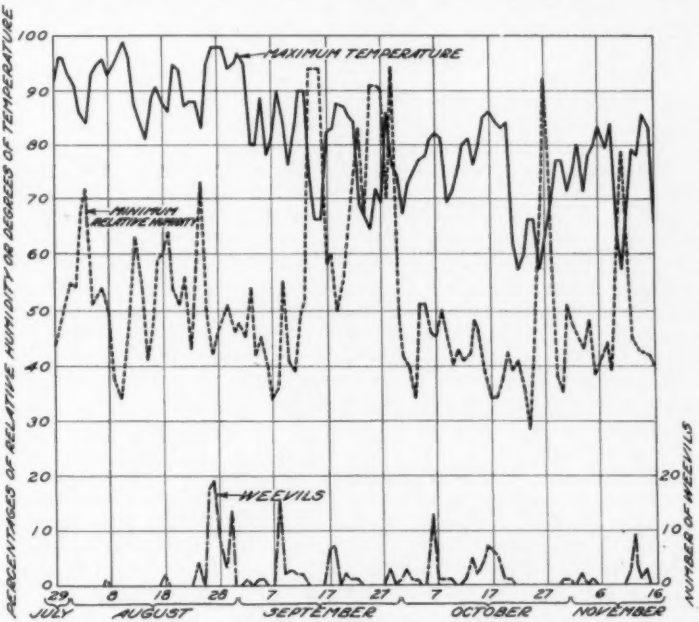

FIG. 2.—Number of boll weevils caught on screen trap, and records of minimum relative humidity and maximum temperature; Florence, S. C., 1924

the insects were in flight at various periods. These periods were more or less definite and came on the following dates: August 26 to 30, September 8 to 18, October 6, October 13 to 18, and November 11 to 14. (Fig. 2.) The weevils were in flight in greatest number during the first period and were less numerous in each successive flight. There was considerable range in the maximum temperatures when dispersal took place, but the lowest was 67° F. More were caught when the daily maximum temperatures ranged between 81° and 96°. On comparing the flight of this species with climatological data, it was evident that other factors modified the influence of temperature and humidity on flight. A careful field-to-field survey conducted over a wide territory when dispersal first began showed that cotton had practically stopped fruiting in most fields and bolls

were opening generally. Lack of food and unsatisfactory breeding places in this case seemed to be the cause of the movement. Rains continuing through the day checked flying, which in one case was resumed as soon as the weather became favorable.

PROPORTION OF SEXES CAUGHT AND TIME OF FLIGHT

A total of 199 weevils were captured on this screen, the sex of most of which was determined. There were 110 males and 88 females. From the time dispersal first began up to September 17 most of the adults were caught on the screen between 9 a. m. and noon, comparatively few being in flight during the afternoon. From this time on the proportion was reversed, and the majority were trapped during the afternoon.

DISPERSAL IN 1925

In 1925 six screens were set up in cotton fields and two at some distance from cotton. It was found that the time of dispersal in all the five unpoisoned fields was different from that in the poisoned field, and that the time of dispersal outside of the fields was different from that in the fields. The data have therefore been assembled according to the location of the screens and are discussed in the following paragraphs accordingly.

In all fields where a screen trap was located, except one, there were from one to three plots staked off, each composed of 100 plants. Weekly examinations were made to determine the number of weevils in each plot, as well as the number of squares, blooms, and bolls on the plants. The infestation of all fields was also noted and in addition several hundred infested forms were picked up and dissected for weevil stages, parasites, etc. These examinations were begun May 21 and continued until November 10.

WEEVIL FLIGHTS IN HEAVILY INFESTED FIELDS

Screens were set up in five fields which were not poisoned at any time during 1925. The first was surrounded by very favorable hibernation quarters. Early counts here showed that from May 21 to July 1 the overwintered weevils averaged 6.14 per 100 plants. They practically destroyed all cotton in this field. (Fig. 3.) The first adults were found on the screen trap July 17, a day after it was set up, but it is very probable that some were flying about before that date. The last one was captured on the screen October 15, but the greatest numbers were caught prior to September 16. There were two rather definite periods during which large numbers were in flight, namely, July 20 to 28 and August 7 to 17.

The second field was about as heavily infested, averaging 5.2 weevils per 100 plants. The soil was more fertile, however, and the cotton never entirely ceased square production. While the insects damaged this crop severely, the injury was not so severe as in the first field. The screen trap was set up July 17 and weevils were found on it the next day. The last one was caught on this trap October 21. The greatest number were taken between July 18 and 28, which was about the same time as recorded for the first heavy flight movement in the first field. However, unlike the above, there was no definite heavy flight period after this one.

The third field was located near favorable winter quarters for the weevils, but had been in corn the year before, and this may account for the smaller initial infestation by these insects, the count averaging 2.4 per 100 plants. The first weevils were caught on this trap July 17, the day after it was set up in the field, and the last one October 19. The largest number were in flight between July 18 and August 21.

The fourth field had fewer early overwintered weevils, the counts averaging 2 per 100 plants. The screen in this field was set up July

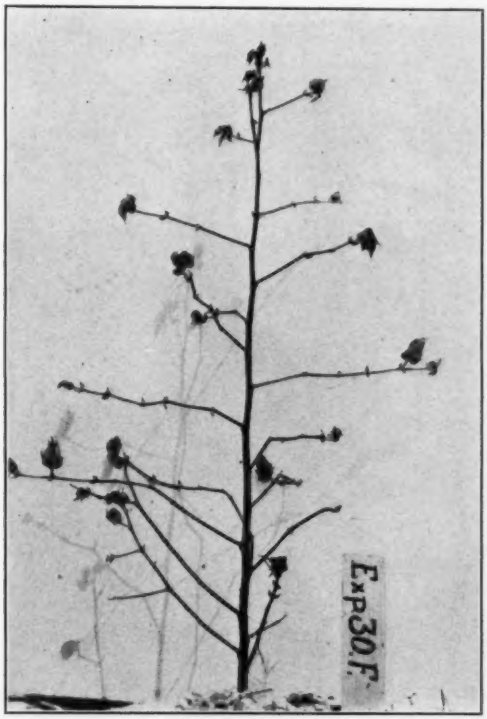

FIG. 3.—Appearance of typical cotton plant (after foliage had been stripped off by hand) in field where screen B was located, photographed August 14

23, and the next day weevils were taken from it. Weevils had undoubtedly been flying for some time before this date, as the largest daily catch was recorded July 24. The greatest number were caught on this trap from this date to August 1, and the last one was taken October 19.

The fifth field had the smallest number of overwintered weevils, the counts averaging 1.5 per 100 plants. The trap was set up July 23, and weevils were caught the next day in larger numbers than in any following 24-hour period. The largest number were in flight between July 24 and August 18, and there was also a smaller flight

from August 31 to September 3. None were found on the trap after October 2. A good crop of cotton was picked from the two last-mentioned fields, chiefly owing to the fact that the bottom crop was set before the infestation caused by migrating weevils became high. (Figs. 4 and 5.)

The summarized data on flight activities, as indicated by the screen traps in all of the five unpoisoned fields, show that weevils were taken from these the day after they were set up. Thus weevils

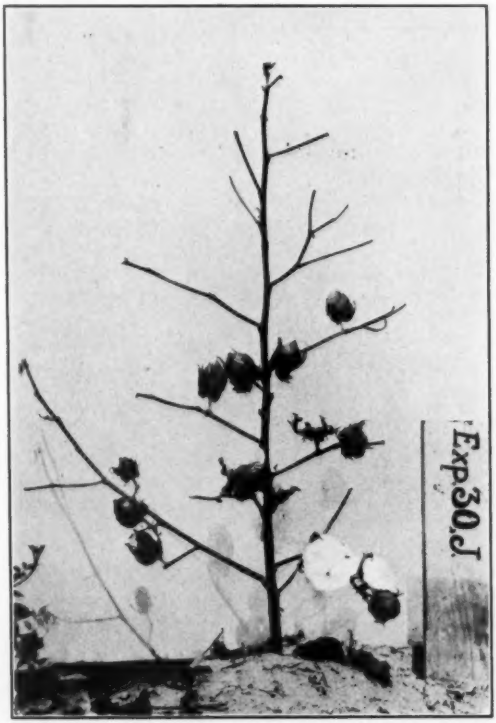

FIG. 4.—Appearance of typical cotton plant (after foliage had been stripped off by hand) in field where screen E was located, photographed August 14

were probably flying about to a certain extent before July 17. The heaviest flights came between July 17 and August 17, the peak being reached July 24. (Fig. 6.)

WEEVIL FLIGHTS IN POISONED, LIGHTLY INFESTED FIELD

The weevil dispersal in one partly poisoned field came later than that in the other fields under observation. The flight movement started July 28 and extended through October 21. The period of greatest flight came between August 7 and September 7, the peak being reached September 5. During this time high temperatures prevailed, the minimum humidity ranging somewhat lower than during

the few weeks prior to the flight period. No weevil counts were made in this field. The fruiting of the plants was approximately the same as on all other cotton in this vicinity.

Since half of the cotton in this field was poisoned, and the initial infestation by overwintered weevils was very small, it is believed that most of the weevils caught on the migration screen came in from other fields more heavily infested. This belief is supported by the weekly square counts, which showed the infestation to be as follows: July 1, 1.6 per cent; July 7, 4.4; July 13, 4.2; July 17, 5.0; July 22, 3.6; July 27, 3.0; and August 1, 13.6.

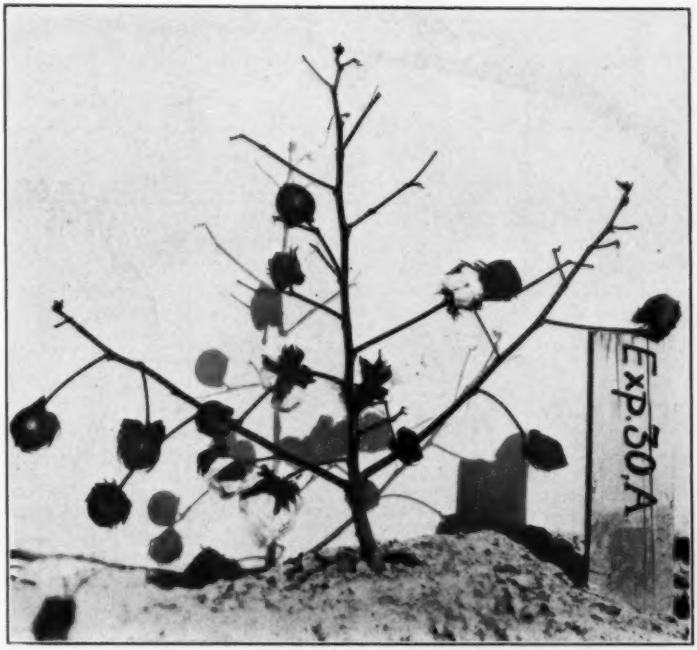

FIG. 5.—Appearance of typical cotton plant (after foliage had been stripped off by hand) in field where screen G was located, photographed August 14

Infestation had begun to increase by August 1, which was before the heaviest weevil movement recorded in this field. At this time square shedding had also begun, a fact which may partly explain the increase at this time. Coincident with the trapping of large numbers of weevils on this screen, the infestation of this field became practically complete.

WEEVIL FLIGHTS BETWEEN FIELDS

One screen was set up in an uncultivated field at a considerable distance from cotton and another in the center of a cowpea field bordered on three sides by cotton. Fewer weevils were caught by these traps than by those located within cotton fields. The first adult was taken July 28 and the last one October 16. A total of 2

were trapped in July, 23 in August, 9 in September, and 2 in October. The records pertaining to these screens show that most of the weevil flights between fields came during August, and more particularly between August 10 and September 2.

PROPORTION OF SEXES CAUGHT AND TIME OF FLIGHT

A total of 912 weevils were caught on the screens, 897 of which were classified as to sex (Table 1), 541 being males and 356 females. Four hundred and ninety were caught in the morning and 367 in the afternoon. When the other 55 were in flight was not determined.

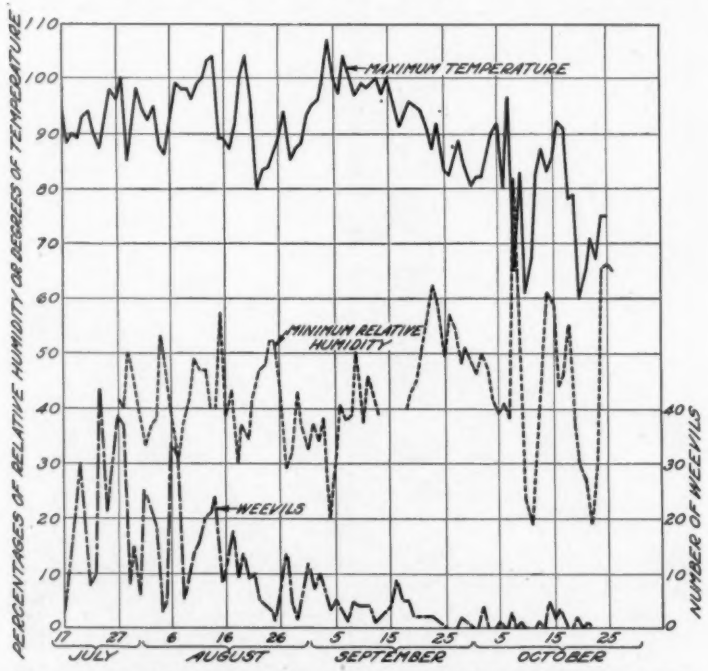

FIG. 6.—Number of boll weevils caught on six screen traps, and records of minimum relative humidity and maximum temperature; Florence, S. C., 1925

TABLE 1.—*Number of male and female weevils captured, and number captured in the forenoon and afternoon, on migration screens, Florence, S. C., 1925*

Screen	Male	Female	Sex undetermined	Total	A. m.	P. m.	Time undetermined	Total
A	126	92	4	222	125	93	4	222
B	83	47	3	133	84	39	10	133
C	72	52	----	124	63	51	10	124
D	144	82	2	228	108	93	27	228
E	37	31	2	70	35	33	2	70
F	6	7	2	15	5	8	2	15
G	62	35	2	99	50	40	----	99
H	11	10	----	21	11	10	----	21
Total	541	356	15	912	490	367	55	912

TRAP-CROP RECORDS, 1925

In 1925 a plot of ground, one-tenth of an acre in extent, was planted to cotton for the purpose of determining when and how long weevils came into cotton fields from hibernation. This planting was examined daily and all weevils were removed. According to the cage records, these insects were through emerging from hibernation by July 1. To be sure that any individuals which might have been overlooked were eliminated, the plot was thoroughly dusted with calcium arsenate. Daily examinations were continued for a week after the dusting but only one weevil was found and killed. The cotton was then free from the insects. Infestation counts were made weekly by examining from 600 to 800 squares at various intervals throughout the plot. (Table 2.) The first signs of weevil damage were noted July 13, when 17 punctured squares were found in one spot, making a total infestation of 2 per cent. On July 16 this dropped to 0.61 per cent, only four punctured squares being found. On July 24 it had increased to 2.83, and from this date it increased rapidly up to 62.66 per cent on August 5. Since all overwintered weevils had been removed from this plot, and no opportunity was given them for reproduction, it is evident that the infestation was produced by migratory weevils coming in from neighboring cotton. These had to fly either through an extensive pine grove, or across an 8-acre tobacco field. The trap-crop records, therefore, check closely with the migration-screen records.

TABLE 2.—*Records of infestation and plant fruiting in trap crop; Florence, S. C., 1925*

	July 9	July 13	July 16	July 24	July 29	Aug. 1	Aug. 5
Percentage of infestation	0	2.00	0.61	2.83	5.70	20.0	62.66
Average number of squares per plant	13.00	18.00	23.33	18.70	8.30	7.0+	2.90
Average number of blooms per plant	.40	.91	1.00+	2.00+	.93	1.0	.44
Average number of bolls per plant	.72	1.40	5.00−	11.00	12.30	16.0	14.00

RELATION OF DISPERSAL TO ENVIRONMENTAL FACTORS, 1925

RELATION OF DISPERSAL TO MAXIMUM TEMPERATURE

During the period when most of the weevils were in flight, daily maximum temperatures varied from 85° to 104° F., the range usually being between 90° and 100°. (Fig. 6.) There was also a well-defined period, from August 28 to September 26, during which the daily temperature maxima were unusually high. On September 4 a peak of 107° was reached. This was followed by a rather definite decline. During this period there was a gradual decrease in the number of weevils caught on the screens. In general, more of these insects were in flight when the maximum was 80° or above, the most favorable temperatures being between 90° and 100°. The coefficient of correlation between maximum temperature and weevil flight was 0.436 ± 0.088836, which indicates a decided correlation. Since there were days when temperature conditions were favorable and yet no weevils were caught on the screens, this factor was of secondary importance.

RELATION OF DISPERSAL TO MINIMUM RELATIVE HUMIDITY

During the time when most weevils were flying, minimum relative humidity readings showed daily fluctuations from 29 to 57 per cent, but there were no definite periods when there were any marked changes. (Fig. 6.) After this time, when the number of weevils caught on the screens began to drop off, the minimum relative humidity records were somewhat lower for a time. No extensive fluctuations occurred, however, until after October 7. The coefficient of correlation between these two factors was such as to indicate that relative humidity was a slight and unimportant factor in weevil flight activities.

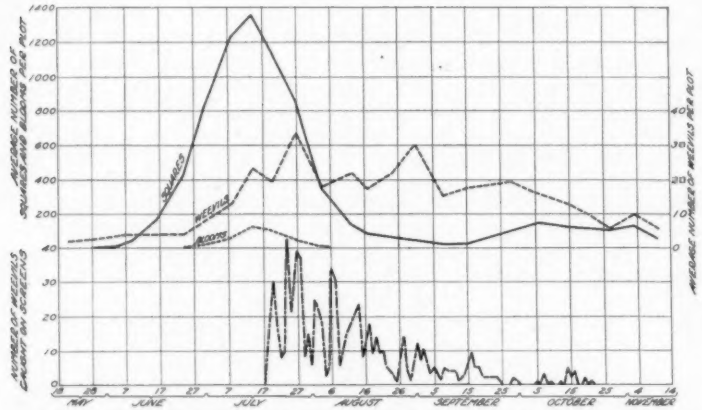

FIG. 7.—Number of boll weevils caught on six screen traps, and records of average bloom and square counts and average weevil population; Florence, S. C., 1925

RELATION OF DISPERSAL TO RAINFALL

Rainfall was scattered and far below the average for this section. Also it usually came before or after the daily flight periods of the weevil. No correlation was noted between weevil flight and rainfall.

RELATION OF DISPERSAL TO SQUARE PRODUCTION

In 1925 the earliest plants began to fruit on or about May 28. From this time on there was a very rapid increase in the total number of squares produced up to July 14,[5] when the peak was reached. Following this, there was an equally rapid decrease until August 12, when there were 1.45 squares per plant. From this date until September 8 the number of squares continued to decrease. Then there was a gradual increase up to October 6, but even at this date there was an average of but slightly more than one to a plant. After October 6 the number of squares decreased gradually to the end of the growing season, with a slight temporary increase on November 3.

In comparing the weevil flights with square production (fig. 7) it is seen that the flights began directly after the peak of production had passed. The greatest number of weevils were in flight when

[5] Average date for all fields.

the available square supply was diminishing rapidly. Then, as the number of squares continued to decrease, the number of weevils flying in the cotton fields decreased, but, as previously noted, the screens outside of cotton fields showed that a considerable interfield movement was taking place. When squares began to develop again there was no corresponding increase in flight activities, but rather a continued decrease. Therefore there was no high degree of correlation between weevil flights and square production in 1925.

RELATION OF DISPERSAL TO WEEVIL POPULATION

From May 21, when counts were started, to June 30 there were relatively few weevils in cotton, but a slight increase occurred from week to week as a result of their continued emergence from hibernation. From June 30 to July 14 there was a rapid increase in the weevil population because of the emergence of the first generation. On July 20 a decrease was noted, but on July 27 there was a considerable increase. On this date there were more weevils in some of the count plots than on any other date in 1925. Fewer were present in the fields from July 27 to August 31, when a second high peak was reached. From this date to the close of the season there were not nearly so many of the insects present in the fields.

Comparing the two curves representing weevil dispersal and population (fig. 7), it is seen that the flights began shortly after the first high point in the weevil count had been reached because of the emergence of the first generation. The heaviest flights were recorded about the time the greatest number were present in the field, when the second generation was issuing. When the second highest point in population was reached August 31, there was no corresponding increase in numbers flying but rather a decrease. Thus there seemed to be no marked correlation between these two factors.

RELATION OF DISPERSAL TO AVAILABLE FOOD SUPPLY AND PLACES FOR BREEDING

While there was no high degree of correlation between time of weevil dispersal and weevil population, or between weevil dispersal and square production, there was a direct relationship among the three taken together. In other words, the percentage of infestation of cotton forms had a direct bearing on weevil flight activities. When the flights began the available square supply was decreasing and the weevil population was increasing. Infestation counts taken July 24 and 25 showed that in four of the five unpoisoned fields the weevils had punctured most of the forms. In the five fields the infestation ranged from 31.6 to 88 per cent, the average being 62.9 per cent. This shows that the weevils were flying about when unpunctured squares began to be scarce. On the other hand, later on in all fields there was a considerable period during which the plants had few or no squares and young bolls developed, and weevils were present in large numbers. Under these apparently favorable conditions for dispersal, only a few weevils were captured on the screens situated within the fields. The two traps located outside of cotton fields, however, showed a considerable interfield movement at this time. The small number of weevils flying when cotton began to fruit again is explained by the fact that for a certain period of time after the top growth of cotton is resumed, the weevil infestation decreases. Late-developed

weevils also feed on the squares, apparently in preparation for hibernation, and there is not so much oviposition by the females. There is thus less stimulation for dispersal than is found earlier. From the foregoing facts it is evident that the dispersal of the boll weevil was first manifested by short flights from row to row, or from one part of a field to another, and that this was induced by a lack of uninfested squares and young bolls. The screens located in cotton fields detected this phase of the dispersal. Later, when the infestation was nearly complete, the flights were extended so that the weevils were dispersing from field to field, as was shown by the traps situated outside of cotton fields. Some of these insects also flew to neighboring cotton fields before the general movement took place, as was proved by the trap-crop records. There was, therefore, a direct correlation between weevil flights and lack of food and breeding places.

RELATION OF DISPERSAL TO DIRECTION OF WIND

A record was kept of the number of weevils caught on the four sides of the screen and also of the direction of the wind, both morning and afternoon. These insects were not blown by the wind, nor did they drift with it, for only 33.01 per cent were caught on the windward side of the screen. (Table 3.) Nor did they fly against the wind so far as could be determined. Apparently, weevils were not influenced to any appreciable extent by moderate winds.

TABLE 3.—*Effect of direction of wind on dispersal of boll weevil; Florence, S. C., 1925*

Direction of wind	Number of weevils caught on sides of screen						Number of weevils drifted	Percentage of drift
	North	South	East	West	Undetermined	Total		
North	35	31	41	27	4	138	35	26.12
Northeast	16	24	16	29	2	87	32	37.65
Northwest	8	8	6	5	1	28	13	48.15
South	46	43	50	58	14	211	43	21.83
Southeast	26	28	31	18	1	104	59	57.28
Southwest	38	34	29	40	56	197	74	52.48
East	6	6	9	14	1	36	9	25.71
West	7	4	9	9	1	30	9	31.03
Calm	20	9	26	15	1	71	------	------
Undetermined	------	3	4	2	------	9	------	------
Total	202	190	221	217	81	911	274	33.01

RELATION OF DISPERSAL TO EMERGENCE OF THE DIFFERENT GENERATIONS

The dates of emergence of the different generations of weevils in 1924 were as follows: First, June 26 to September 30; second, July 24 to October 29; third, August 17 to November 14; and fourth, September 12 to October 31. At the time dispersal began in large numbers, namely, on August 26, there were weevils of the first, second, and third generations in the field. (Fig. 8.)

In 1925 the dates of emergence of the four generations of weevils were as follows: First, July 1 to August 17; second, July 23 to October 4; third, August 20 to September 23; and fourth, October 19 to November 28. Dispersal began July 17 and was at its height between July 24 and August 7. The dispersal flight of the weevil

in 1925 also showed little relationship to the emergence of the different generations. (Fig. 9.)

From the time the first summer-generation weevils begin to issue from the infested squares, which is usually late in June or early in July in this section, until the first killing frost in October or November, there is a steady daily emergence of newly transformed weevils, either from infested squares or bolls. The number varies according to the fruiting condition of the cotton plant or according to climatic conditions, and there is a so-called "peak" to the emergence of any one generation. If there were a direct relationship between migration and the life history of the weevil, there would be a more or less

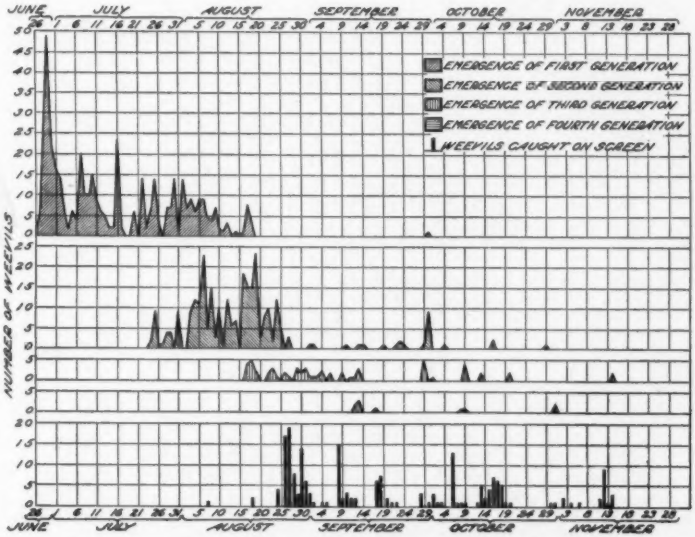

FIG. 8.—Emergence of different generations of boll weevils in 1924 and number of weevils caught on screen trap

continuous daily movement of weevils, fluctuating, of course, with weather conditions, increasing as the weevil population increased, or when a peak of emergence was reached. This, however, did not occur.

RELATION OF DISPERSAL TO DIRECTION OF FLIGHT

It was noticed that on all screens where considerable numbers of weevils were caught, more were found entangled on one side of the trap than on the others. Sometimes this varied throughout the season. For example, on the screen in the poisoned field more were collected from the east side up to August 14. After this time more came in from the north, until by August 20 the accumulated totals collected on this side exceeded those from the east. On September 5 the flight was from the east. On the two days following about the same number were caught on the east side as on the north. Following this, the movement from the north again became the greatest.

For the entire season, the greatest number of weevils were removed from the north part of this trap. In another field a majority were found on the south section of the screen, in two on the east, in two others on the west, while in two fields the numbers were too small to warrant drawing definite conclusions.

SUMMARY

The cotton-boll weevil has a pronounced habit of dispersal by flight during the summer months, either from one part of a field to another or between fields. Flying began on July 17 in 1925, but not until August 26 in 1924.[6] The weevils commence to fly earlier in heavily infested fields than in those only slightly infested, the tendency being to leave the former and fly to the latter. Most of these insects fly during the morning, unless it happens to be too cool or rainy, when dispersal takes place in the afternoon, provided the temperature rises, or it clears off. More weevils are in flight at the beginning of the migratory movement than later. Males seem to be more active than females, more being caught on the screens. While the weevils may fly when the maximum temperature is between 60° and 80° F., the most favorable conditions are between 80° and 100° F. There are days when the maximum temperature is favorable, however, and no weevils are in flight. This factor is of secondary impor-

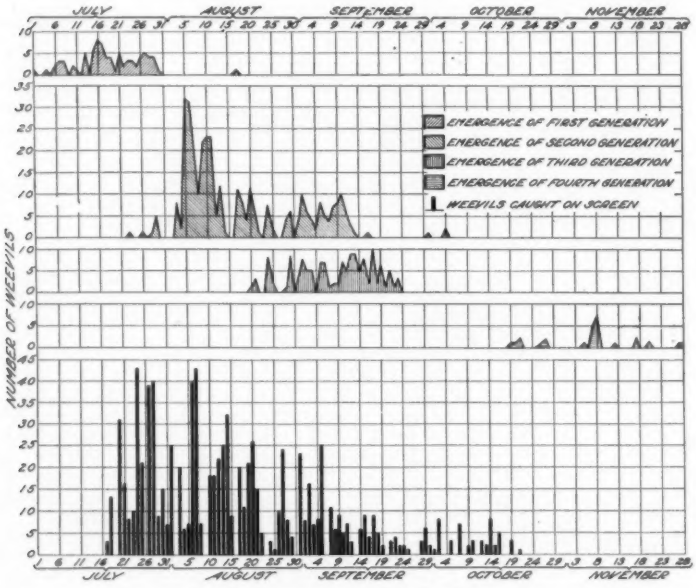

FIG. 9.—Emergence of different generations of boll weevils in 1925 and number of weevils caught on all screen traps

[6] In certain heavily infested fields, weevils were flying before this date.

tance and acts only after the impelling instinct to fly has been awakened.

Such factors as degree of minimum relative humidity, number of squares on the plants, number of weevils in the field, direction of moderate winds, or emergence of a definite generation of weevils, have little influence on the extended flight activities of this species. There is, however, a distinct relationship between degree of infestation in a field and weevil flights. When the percentage of infestation reaches a certain point, which has not yet been determined, these insects become restless and fly. At first their flights are short ones, from row to row, or from one part of a field to another. Later, however, the more heavily infested fields are deserted for those which have been only slightly infested because of poisoning or a low early infestation by overwintered weevils.

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STATUS OF THE PARASITES OF THE HESSIAN FLY, PHYTOPHAGA DESTRUCTOR (SAY), IN PENNSYLVANIA, MARYLAND, AND VIRGINIA [1]

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INTRODUCTION

It has long been known that parasites play an important rôle in the natural control of the Hessian fly, *Phytophaga destructor* (Say), but most of the accounts so far published have contained little information concerning the relationships of the parasites to their host and to each other. Such knowledge, however, is important, not only in estimating the value of the parasites as a whole in the control of the Hessian fly, but also in determining the relative importance of the individual parasites.

To obtain information of this nature an intensive study of the parasites of the Hessian fly has been carried on for several years in the eastern part of the United States, and it is the purpose of this paper to set forth some of the results of this work.

The data here assembled are from material collected for 10 consecutive years from widely separated localities in the wheat-growing regions of Pennsylvania, Maryland, and Virginia, from Lycoming County, Pa., on the north, to Augusta County, Va., on the south.

METHODS OF INVESTIGATION

In obtaining the records of the parasites attacking the Hessian fly of the spring generation, certain localities in which normal farm practice is followed were selected from the important wheat-growing counties within the area under observation. One or more collections of infested wheat plants were made from each of these points. These samples were examined in the laboratory, the Hessian fly puparia removed and classified, and the apparently sound puparia reared to obtain the parasites or flies that they might contain. In those cases where more than one collection was made in a locality, the data were consolidated and treated as a single collection. The number of puparia thus assembled from each county averaged 310.

In order that all the species of parasites might have a fair showing, collections made earlier than June 15 were not included in the table of relative abundance, and most of the collections were taken after the first of August. It was found necessary thus to take into consideration the time of collection because of the fact that certain of the parasites, for instance, *Platygaster vernalis* and *P. herrickii*, which oviposit in the egg of the host, obviously enter the host considerably earlier than the other parasites. If collections had been made before

[1] Received for publication Oct. 22, 1927; issued March, 1928.

[2] The authors wish to express their obligations to the late W. R. McConnell and P. R. Myers, by whom these investigations were begun, and who contributed substantially to the accumulation of the data used herein. Credit is also due to the various temporary assistants and collaborators who have given their services to this project from time to time. Appreciation is extended to A. B. Gahan for the original determination of most of the species involved and to C. M. Packard, W. H. Larrimer, W. R. Walton, and J. R. Horton, all of the Bureau of Entomology, for helpful criticisms.

the later ovipositing parasites had entered the host there would have been undue discrimination in favor of those which oviposit early.

These parasites all belong to the order Hymenoptera. Of those mentioned in this paper 3 are serphoids of the genus Platygaster and 15 are chalcidoids.

The parasites were reared most successfully in shell vials inserted in plaster-of-Paris blocks. This holder was devised by W. R. McConnell early in the progress of the investigations. It consists of a block of plaster 18 inches long by 8 inches high by 1½ inches thick, with a substantial bulge at the back. Holes about 15 mm. deep and of sufficient diameter to receive 9 mm. by 33 mm. shell vials are spaced an inch apart each way, 119 in all, over the flat surface of the block. The block stands on one long side, and a shallow trough is excavated along the top. Four vertical holes evenly spaced along the bottom of the trough are drilled slightly more than half way to the bottom of the slab. This allows water poured in the trough to penetrate the plaster quickly and uniformly. The puparia are placed in the vials, 10 to each vial, the mouth of the vial is plugged snugly with a piece of cotton, and this end is fitted into one of the holes in the front of the block.

PARASITISM OF THE HESSIAN FLY OF THE SPRING GENERATION

From Table 1 it may be seen that in the territory under observation the average annual parasitism of the Hessian fly of the spring generation was 62 per cent.

It was interesting to observe that the average mortality of the Hessian fly amounted to 96 per cent, which is considerably in excess of the mortality that was positively determined as caused by parasites. There is evidence, however, to indicate that some of this additional mortality was the result of parasitism, the traces of which had become obliterated. This was shown to be the case by dissections of Hessian fly puparia taken from selected areas in fields near the beginning and again near the end of the season. Three such sets of observations were made in different localities and in different years and the results in each case showed a greater total parasitism in the first collection than in the last. At the same time, in the last collection an increase was found in the number of puparia dead from undetermined causes. As the number of individual flies remained the same throughout the season, the total amount of parasitism could not actually have decreased, and the difference must be looked for in unrecognizable material. It might be added that in a great many cases, in the course of examining Hessian fly puparia, traces of dead chalcidoids or Platygaster larvae were found in an almost unrecognizable state, which also indicates that some of the unrecognizable material within dead puparia was of such origin.

Table 1 also shows the relative abundance of the 18 species of parasites found to prey on the Hessian fly in this section. Three of these parasites belonging to the genus Platygaster of the superfamily Serphoidea are *herrickii*, *hiemalis*, and *vernalis*. The remaining 15 species belong to the superfamily Chalcidoidea. *P. vernalis* was more efficient than any one of the other parasites. The other two Platygasters were of insignificant importance, because *hiemalis* normally attacks only the fall generation instead of the spring generation of the fly, and *herrickii* is prolific only in a more southern climate.

TABLE 1.—*Relative value of the parasites of the Hessian fly of the spring generation in the wheat regions of Pennsylvania, Maryland, and Virginia, and their relation to the total mortality of the host, 1915 to 1924*

Year	Number of collections	Total number of puparia	Average number of puparia per collection	Parasitism of the Hessian fly by—																	Total parasitism	Hessian flies dead from unrecognizable causes	Total mortality of Hessian flies
				Chalcidoids														Platygasters					
				Eupelmus allyni (French)	Merisus destructor (Say)	Pleurotropis epigonus (Walker)	Merisus tebricollis Girault	Tetrastichus carinatus Forbes	Eupteromalus multicopereus (Lindemann)	Chelonenurus eleganş (Dalman)	Centrodora speciosissimus (Girault)	Nemiscomelus fulviyes (Forbes)	Eupelmus saltator (Lindemann)	Polyscelis modestus Gahan	Ditropinotus aureoviridis Crawford	Calliitula bicolor Spinola	Eurytoma phoebus Girault	Eurytoma n. sp.	Undetermined chalcidids	Total chalcidids	Platygaster herrickii Packard	Platygaster hiemalis Forbes	Platygaster vernalis (Myers)		
				Per cent	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1915	5	1,882	376	1.51	2.79	1.45	0.37	0.25	0.06	0.25	0.02	0.10							16.39	22.99			34.02	57.01	93.28
1916	7	4,947	707	6.77	6.18	.46	1.42	1.72	.01	0.25	0.02	.10							23.32	40.28	0.51		18.02	58.81	95.37
1917	12	1,658	138	6.03	3.02	3.59	1.32	.10		.12	.81		0.09						25.76	40.92			12.97	53.89	94.04
1918	5	1,825	365	5.39	2.97	1.81	.65	.02	.04	.06	.02			.04			.08		21.64	32.64			26.68	59.32	95.43
1919	16	5,225	327	3.19	5.72	1.35	1.03	.43			.05		.11	.03					23.86	35.77			22.09	57.86	93.21
1920	23	6,278	273	2.93	3.24	1.26	.32	.19		.06	.09	.02			.01				25.51	33.62			25.23	58.85	92.12
1921	15	5,909	394	3.34	3.33	.18	.25	.79	.02		.03				.01				34.43	42.38		0.01	25.11	67.50	98.41
1922	15	4,455	297	4.14	6.74	.12	.31	.04	.02		.06	.07	.07				0.10		39.16	50.85	.26	.04	14.67	65.82	98.68
1923	10	2,852	285	2.82	3.39	.27	.09	.04	.04										21.63	28.28	.03	.13	34.60	62.91	91.19
1924	15	3,139	209	4.03	2.64	.84	.54	2.07	.06	.04		.02	.14	.02					29.04	39.44	.03	.12	35.08	74.67	94.85
Average	12.3	3,817	310	4.02	4.00	1.13	.63	.57	.03	.05	.11	.02	.04	.01	.01	.01	.01		26.07	36.72	.08	.02	24.84	61.66	95.57

Of the chalcidoids, five species were found attacking the Hessian fly every year. These were, in order of importance, *Eupelmus allynii, Merisus destructor, Pleurotropis epigonus, M. febriculosus,* and *Tetrastichus carinatus.* The remaining 10 species were comparatively scarce, and in some years a few of them were not recovered at all.

The percentage of the individual chalcidoids is relative rather than absolute because some parasites had emerged at the time of collection. Their occurrence as such, however, could be determined by the emergence holes and pupal remains. These have been classified in the table under the heading "Undetermined chalcidoids," and when they are added to the chalcidoids which were reared and determined there is shown an annual average total parasitism of chalcidoids of 37 per cent.

In order to check the rearing records by actual field conditions, dissections were made of Hessian fly puparia as they were found in the field. This eliminated any modifying effect which might result from unnatural confinement in rearing cages. The combined results of two such dissection records of 99 Hessian fly puparia taken from a field in Carlisle, Pa., in 1918 showed a total parasitism of 70 per cent and a total mortality of 95 per cent. Six such observations, based on 950 puparia collected from a field in Mount Holly Springs, Pa., in 1919, showed a total parasitism of 71 per cent and a total mortality of 92 per cent. Four such observations, based on 586 puparia collected from a field in Mount Holly Springs in 1920, showed a total parasitism of 52 per cent and a total mortality of 99 per cent. Five similar observations, based on 510 puparia collected at New Windsor, Md., in 1921, showed a total parasitism of 53 per cent and a total mortality of 97 per cent. An average of these figures shows a total parasitism of 62 per cent and a total mortality of 96 per cent, which is very close to the average figures obtained in the rearing records shown in Table 1.

PARASITISM OF THE HESSIAN FLY OF THE FALL GENERATION

The Hessian fly of the fall generation was found to be attacked almost solely by the serphoid parasite *Platygaster hiemalis.* During the nine years from 1914 to 1922, inclusive, in the wheat-growing regions covered by these investigations, the annual mortality of the Hessian fly of the fall generation caused by this parasite ranged from 16 to 40 per cent with a yearly average of 28 per cent.[3]

Records from material gathered in 10 counties in Pennsylvania, in 1923, showed an average of 55 per cent of parasitism by *hiemalis.* Data obtained during this year from other localities were unreliable owing to the scarcity of the Hessian fly.

HYPERPARASITISM

Hyperparasitism is prevalent among the parasites of the Hessian fly, but there is no evidence that any discrimination is made between parasite and fly in the selection of a host.

Platygaster vernalis is especially subject to hyperparasitism owing to its occurrence in the host very early in the season. The following parasites have been reared from cocoons of *Platygaster vernalis: Eupelmus allynii, Merisus destructor, M. febriculosus, Tetrastichus*

[3] HILL, C. C. PLATYGASTER HIEMALIS FORBES, A PARASITE OF THE HESSIAN FLY. Jour. Agr. Research 32: 261–275, illus. 1926.

carinatus, *Cheiloneurus elegans*, *Callitula bicolor*, *Nemicromelus fulvipes*, *Eupteromalus micropterus*, *Eupelminus saltator*, *Centrodora speciosissimus*, and *Polyscelis modestus*.

There is evidence which indicates that the chalcidoids prey on one another, as dissection records have shown the presence of more than one chalcidoid larva in a host. Owing to the unrecognizable condition of the parasite killed, it was usually impossible to determine the species and therefore only a few records have been made. *Merisus destructor* was found to have been parasitized by one of its own species and by *Eupelmus allynii*. *Tetrastichus carinatus* was found parasitized by *E. allynii*, *E. allynii* by *T. carinatus*, and an internal parasite considered to be *Pleurotropis epigonus* by *E. allynii*.

The Platygaster parasites, *vernalis*, *hiemalis*, and *herrickii*, always oviposit directly in the egg of the fly, and are, therefore, usually primary in their parasitic habits.

It may be assumed that any one of the other parasites is capable of being hyperparasitic. For this reason such parasites as are of little importance as controlling factors because of their scarcity might be considered as detrimental rather than beneficial to the attainment of biological control of the Hessian fly.

SUMMARY AND CONCLUSION

The average annual parasitization of the spring generation of the Hessian fly, based on 10 consecutive years of observation, in the region in Pennsylvania, Maryland, and Virginia, from Lycoming County, Pa., to Augusta County, Va., was found to be 62 per cent.

The average total mortality amounted to 96 per cent. The cause of the mortality additional to the 62 per cent mentioned above was unrecognizable at the time of examination. Part of this additional mortality, however, was undoubtedly the result of parasitism.

Eighteen species of parasites were found to attack the Hessian fly in these regions.

The most abundant parasite of the spring generation was *Platygaster vernalis*. Next to this one in order of abundance came *Eupelmus allynii*, *Merisus destructor*, *Pleurotropis epigonus*, *M. febriculosus*, and *Tetrastichus carinatus*. The remaining parasites attacking the Hessian fly of the spring generation were comparatively scarce.

The fall generation in this region was found to be normally parasitized only by *Platygaster hiemalis*. The average annual mortality of the Hessian fly from this source during the years from 1914 to 1922 amounted to 28 per cent. In 1923 records showed an average of 55 per cent for the State of Pennsylvania.

In this section of the country the two species *Platygaster hiemalis* and *P. vernalis* were the most efficient parasites. *P. hiemalis* should be ranked first in importance owing to its abundance and to the fact that if it were absent there would be no other parasite to attack the fly of the fall generation.

The effectiveness of the remaining parasites, with the exception of *Platygaster herrickii*, is somewhat offset by the likelihood that they may prey on one another and on the Platygasters.

Complete control of the Hessian fly by parasites can not be expected, but it is evident that in the regions under observation they are an important factor in checking its increase.

TAXONOMIC STATUS OF THE DECIDUOUS-FRUIT PARATETRANYCHUS WITH REFERENCE TO THE CITRUS MITE (P. CITRI) [1]

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INTRODUCTION

While making a detailed biological study of what has been held to be the European red mite (*Paratetranychus pilosus* Can. and Fanz.) at the Yakima (Wash.) field laboratory of the Bureau of Entomology, the junior writer became interested in the question whether or not this species is distinct from the citrus mite (*P. citri* McG.) of Florida and California. Opinions have been expressed by various writers on both sides of the question.

The earliest report of the occurrence in America of a Paratetranychus on deciduous fruit trees was made by Ewing (*6*)[2] in Oregon in 1912.[3] He considered the mite found there on apple, peach, and prune to be "the well-known red spider of citrus trees," known then as *Tetranychus mytilaspidis* Riley. Essig (*4*), in 1913, reported that the citrus mite occurred in California on apple, prune, and peach. Caesar (*3*) found the deciduous-fruit mite in Canada in 1912, and Frost (*7*) found it in Pennsylvania in 1918, both of them giving it the name of *P[aratetranychus] pilosus* Can. and Fanz. Garman (*8*) reported the occurrence of a mite in Connecticut in 1921, "which seems to be *Paratetranychus pilosus* Can. and Fanz," and, in 1922, Smith (*16*) reported the European red mite from Idaho, stating that specimens had been determined as such by Ewing.

Garman's article prompted Essig (*5*) to send specimens of the mites from deciduous and citrus trees in California to Garman, who reported that "no characters could be discovered which would separate the California material from the European red mite." Specimens were also sent to Ewing, who reported that the species occurring on deciduous and citrus fruit trees in California were the same. McGregor (*11*) showed conclusively in 1916 that the citrus mite was not *Tetranychus mytilaspidis* Riley and that it had never been described. He therefore described it under the name *Tetranychus citri*, and has later placed the species in the genus Paratetranychus (*12, p. 672*). Essig (*5*), however, concluded that the mite found on both deciduous and citrus trees in California was *Paratetranychus pilosus* and that therefore *P. citri* was a synonym. Subsequent writers have mostly followed Essig's conclusions, in spite of the fact that in 1919 McGregor (*12*) had described the anatomical differences between *P. pilosus* and *P. citri*.

It seemed to the junior writer that the evidence either for or against the synonymy of these species was not entirely conclusive.

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[1] Reference is made by number (italic) to "Literature cited," p. 180.

[2] Banks (*1*) described *Tetranychus (Paratetranychus) bicolor* from oak and chestnut, and *Tetranychus (Paratetranychus) viridis* from pecan.

The only evidence that existed in favor of the synonymy was a great similarity in appearance and habits, which often occurs with distinct species, and the evidence against synonymy consisted in a difference in food plants and in certain anatomical differences which could be distinguished only with oil-immersion lenses supplemented by keen eyesight, and which were therefore possibly open to question. Correspondence was accordingly begun with the senior writer, with the result that a comparative study of the habits and appearance of the two forms has been made, and the anatomy of each has also been restudied.

METHOD OF STUDY

Because the deciduous-fruit mite occurred abundantly at Yakima, Wash., most of the comparative tests were made there by the junior writer. Supplementary tests were also made by the senior writer at the Lindsay, Calif., laboratory of the Bureau of Entomology. The deciduous-fruit mite occurring at Yakima has been determined by Ewing as the European red mite (*Paratetranychus pilosus* Can. and Fanz.), although, as shown later, this determination may be questioned. Through the kindness of R. E. Campbell, of the Bureau of Entomology, United States Department of Agriculture, several shipments of the citrus mite were sent to Yakima on lemon leaves and fruit from Alhambra, Calif. The Yakima experiments were conducted on potted seedling grapefruit trees raised from the seed of Florida grapefruit, on green lemons sent from Alhambra, and on apple, pear, and peach trees planted in the laboratory yard. It is thought that the grapefruit seedlings formed an entirely suitable food plant for the citrus form, because some of the mites were able to maintain themselves on this food from September, 1924, to June, 1925, the seedlings being kept indoors during the winter. In order to keep definite records of individuals, a rearing cell (Fig. 1, B) was used, similar to that perfected by McGregor (*13, p. 22*) in biological work with *Tetranychus bimaculatus* Harvey. This cell had been used very successfully at the Yakima laboratory in the biological studies of the deciduous-fruit mite. The experiments consisted of (1) mating experiments, both with citrus males × deciduous-fruit females, and with deciduous-fruit males × citrus females, and (2) feeding experiments in which citrus individuals were reared on deciduous trees and deciduous-fruit individuals on citrus seedling trees or on lemons. A number of minor observations were also made bearing on the problem. Feeding tests only were made at Lindsay, Calif.

MATING EXPERIMENTS

The experiments in mating were undertaken because it seemed evident that if these two forms were of the same species they would mate readily and would produce offspring of both sexes, whereas if the two forms were distinct in species such would not be the case. It had been previously established that unfertilized females of these mites deposit eggs normally, and the eggs hatch, but that the resulting mites are always males (parthenogenesis). This was abundantly demonstrated in the course of the biological work with the deciduous-fruit mite at Yakima, and in earlier work by the senior author in South Carolina (*13*). If the two forms were distinct, the females of either form should produce only males when crossed with males of the other form.

No difficulty was experienced in getting males of either form to mate with females of the other form. Copulation apparently occurred as readily as when the two sexes were of the same form, and lasted about the same length of time. The females used were previously isolated in the deutonymphal stage, so that there would be no possibility of their being fertilized by males of their own form. Males of the other form were placed with them as soon as they cast their nymphal skin. Copulation usually occurred within a few minutes, and care was taken to observe this act and make a record of it. All cases where copulation was not actually observed were thrown out. The females were allowed to remain in the same cell, being always on their native food plant, until they had deposited eggs and had either died or escaped. With a few exceptions each

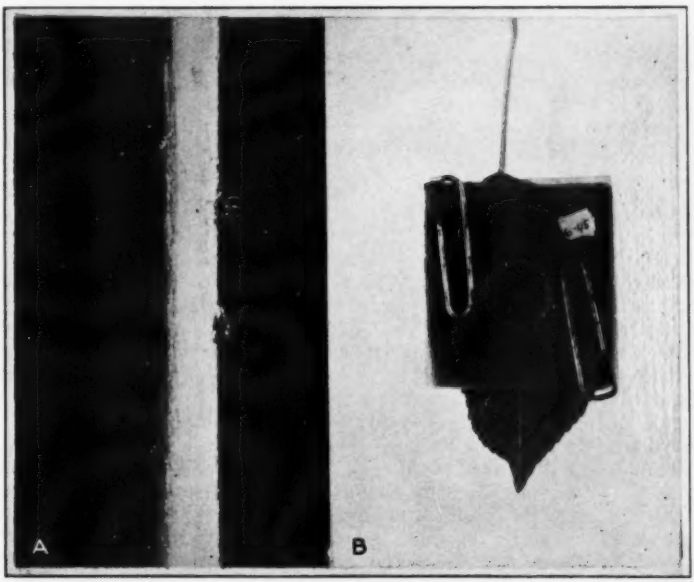

FIG. 1.—Northwestern red mite: A, Adult females on petiole of apple leaf; B, rearing cell used in breeding tests, attached to apple leaf

cell contained only one female, and individual records were made of the life of the female, the number of eggs deposited, and the number and sex of the resulting progeny.

CITRUS MALES MATED WITH DECIDUOUS-FRUIT FEMALES

In crossing citrus males with deciduous-fruit females, females were used that had been reared on apple, peach, or pear. This work was started at Yakima in the fall of 1924, but too late to obtain definite results, as cold weather caused the foliage to be shed and put a stop to the development of the eggs and the young. In May and June, 1925, 14 deciduous-fruit females were mated with citrus males; the results of this experiment are given in Table 1.

TABLE 1.—*Results of mating male citrus mites with female deciduous-fruit mites at Yakima, Wash., in 1925*

No.	Date of mating	Food plant	Length of life of female	Number of eggs deposited	Number of eggs hatched	Number of progeny		
						Male	Female	Not maturing
			Days					
1	Apr. 30	Apple	27	65	17	12	0	5
2	May 1	do	12	25	25	13	0	12
3	May 2	do	15	28	26	25	0	1
4	May 3	do	20	58	57	45	0	12
5	May 2	Peach	17	37	34	22	0	12
6	do	do	40	90	81	45	0	36
7	May 4	do	13	27	27	27	0	0
8	May 5	do	24	56	44	36	0	8
9	June 29	do	9	16	10	10	0	0
10	Apr. 30	Pear	13	25	25	16	0	9
11	do	do	25	56	42	9	0	33
12	do	do	13	9	9	0	0	9
13	do	do	11	15	15	7	0	8
14	May 1	do	18	28	19	13	0	6
	Total			535	431	280	0	151

Average number of eggs per female, 38; percentage of eggs hatching, 81; percentage of eggs producing adults, 52; percentage of young developing into males, 65; percentage of young developing into females, 0; percentage of young not maturing, 35.

Of 535 eggs resulting from these crossings, 431, or 81 per cent, hatched, and 280, or 52 per cent, produced males. No females were produced; and although only a little more than half of the eggs produced males, it does not follow that, if there were any potential females, they were all among the eggs that failed to hatch or among the young that failed to mature. Proof of this statement will be given later. It can only be concluded that these deciduous-fruit females were not fertilized by the citrus males with which they were crossed, and that the young were parthenogenetic. This conclusion is supported by a comparison of these figures with results obtained from deciduous-fruit females mated with deciduous-fruit males at approximately the same time of year. Fourteen citrus × deciduous-fruit matings produced 535 eggs, of which 431, or 81 per cent, hatched. Fourteen deciduous-fruit × deciduous-fruit matings produced 484 eggs, of which 408, or 84 per cent, hatched. The percentage of hatching is thus very similar. A comparison of the progeny of these two crossings, the latter somewhat amplified in number, is given in Table 2.

TABLE 2.—*A comparison of the progeny of female deciduous-fruit mites mated with male citrus mites and with male deciduous-fruit mites, at Yakima, Wash., in 1924 and 1925*

Item	Male citrus mite × female deciduous-fruit mite.		Male deciduous-fruit mite × female deciduous-fruit mite	
	Number	Percentage of hatching eggs	Number	Percentage of hatching eggs
Eggs hatching	431		* 468	
Young failing to mature	151	35	100	21
Young developing into males	280	65	154	33
Young developing into females	0	0	214	46

* This number includes 60 eggs in addition to the 408 mentioned in the text.

Sixty-five per cent of the hatching eggs that resulted from the citrus × deciduous-fruit cross produced males, whereas only 33 per cent, or relatively about half as many, of those resulting from the deciduous-fruit × deciduous-fruit mating were males. Evidently, in the first case, the females were all replaced by males. Matings of deciduous-fruit males with deciduous-fruit females invariably produce some females, in cases where the number of young maturing is sufficiently large, and usually more females than males.

DECIDUOUS-FRUIT MALES MATED WITH CITRUS FEMALES

In the crosses of deciduous-fruit males with citrus females, the latter had been reared on lemons or on grapefruit foliage. Experiments started in the fall of 1924 were carried to completion, since the potted grapefruit seedlings did not shed their foliage, and could be taken indoors. Additional experiments were made in April and May, 1925. Four females were mated in 1924 and six in 1925, as shown in Table 3. The food plant in all these cases was grapefruit foliage.

TABLE 3.—*Results of mating male deciduous-fruit mites with female citrus mites at Yakima, Wash., in 1924 and 1925*

No.	Date of mating	Length of life of female	Number of eggs deposited	Number of eggs hatched	Number of progeny		
					Male	Female	Not maturing
	1924	*Days*					
1	Sept. 12	23	12	7	2	0	5
2	Sept. 19	16	12	12	12	0	0
3	....do	17	15	14	12	0	2
4	Oct. 1	14	7	5	4	0	1
	1925						
5	Apr. 20	18	18	16	14	0	2
6	Apr. 29	18	17	17	11	0	6
7	Apr. 30	17	13	12	12	0	0
8	May 1	16	14	14	4	0	10
9	May 2	16	11	11	3	0	8
10	May 3	12	8	8	7	0	1
	Total		127	116	81	0	35

Average number of eggs per female, 12.7; percentage of eggs hatching, 91; percentage of eggs producing adults, 64; percentage of young developing into males, 70; percentage of young developing into females, 0; percentage of young not maturing, 30.

In this case it is even more conclusive that the young are of parthenogentic origin, since the males constitute 64 per cent of all the eggs deposited, and 70 per cent of the eggs that hatched, and there were no females.

These reciprocal crossings produced 431 hatching eggs from 14 females in one case, and 116 hatching eggs from 10 females in the other case. Only males were produced. This does not happen when females of either the deciduous-fruit or the citrus form are mated with males of their own form. The only conclusion that can be drawn from these experiments is that, although copulation took place, the females were not fertilized, and that therefore the two forms are distinct species.

MATING EXPERIMENTS WITH DECIDUOUS-FRUIT MITES FROM CONNECTICUT AND WASHINGTON

In the spring of 1926 the junior writer obtained some winter eggs of Paratetranychus from Connecticut, through the kindness of Philip Garman, of the Connecticut Agricultural Experiment Station. Mites were reared from these eggs, and matings were made with mites taken from the orchards near Yakima, Wash. Care was observed to use only virgin females. In most cases the males were placed in cells containing only females in the quiescent state following the deutonymphal period. These usually mated as soon as the females emerged. In Table 4 the results of mating nine Connecticut females with Washington males are given. Five of these matings resulted in female progeny, although only 20 per cent of the progeny reared to maturity were females.

TABLE 4.—*Results of mating Washington male mites with Connecticut female mites at Yakima, Wash., in 1926*

No.	Date of mating	Number of eggs deposited	Number of eggs hatched	Number of progeny		
				Male	Female	Not maturing
1	Apr. 19	17	15	1	0	14
2	do	8	8	3	2	3
3	Apr. 20	7	7	4	0	3
4	do	26	23	5	1	17
5	Apr. 22	40	12	4	1	7
6	Apr. 24	33	18	0	1	17
7	Apr. 25	5	4	2	1	1
8	do	7	7	3	0	4
9	Apr. 27	8	8	2	0	6
	Total	151	102	24	6	72

Percentage of eggs hatching, 68; percentage of young developing into males, 24; percentage of young developing into females, 6; percentage of young not maturing, 70.

Table 5 presents the results of mating 11 Washington females with a like number of Connecticut males. In seven of these cases female progeny resulted, although only 27 per cent of those maturing were females.

TABLE 5.—*Results of mating Connecticut male mites with Washington female mites at Yakima, Wash., in April, 1926*

No.	Date of mating	Number of eggs deposited	Number of eggs hatched	Number of progeny		
				Male	Female	Not maturing
1	Apr. 19	22	20	4	0	16
2	do	18	16	4	0	12
3	Apr. 20	15	13	1	0	12
4	do	23	22	5	1	16
5	do	18	15	3	3	9
6	Apr. 21	8	3	0	1	2
7	Apr. 22	17	13	5	3	5
8	Apr. 23	8	6	1	2	3
9	Apr. 25	15	15	5	0	10
10	do	13	13	5	1	7
11	Apr. 26	16	12	2	2	8
	Total	173	148	35	13	100

Percentage of eggs hatching, 86; percentage of young developing into males, 24; percentage of young developing into females, 9; percentage of young not maturing, 67.

As a check on these experiments, Connecticut females were also mated with Connecticut males, as shown in Table 6; of four such cases two resulted in female progeny, 13 per cent of the total being females. Seven Connecticut females were isolated and not allowed to mate; Table 7 shows that in none of these cases were any female progeny produced.

TABLE 6.—*Results of mating Connecticut male and female mites, at Yakima, Wash., in April, 1926*

No.	Date of mating	Number of eggs deposited	Number of eggs hatched	Number of progeny		
				Male	Female	Not maturing
1	Apr. 21	44	(?)	11	3	(?)
2	Apr. 25	61	(?)	9	0	(?)
3	do	4	4	3	1	0
4	do	4	4	3	0	1
	Total	113		26	4	

Percentage of mature progeny male, 87; percentage of mature progeny female, 13.

TABLE 7.—*Progeny of unmated Connecticut female mites, isolated at Yakima, Wash., in 1926*

No.	Number of eggs deposited	Number of eggs hatched	Number of progeny		
			Male	Female	Not maturing
1	4	4	4	0	0
2	9	7	4	0	3
3	2	2	1	0	1
4	6	5	1	0	4
5	18	13	2	0	11
6	20	16	1	0	15
7	5	4	1	0	3
Total	64	51	14	0	37

Percentage of eggs hatching, 80; percentage of young developing into males, 27; percentage of young developing into females, 0; percentage of young not maturing, 73.

Owing to other work it was not possible to follow the development of the progeny of these matings as closely as in the work with the citrus and deciduous-fruit forms. In most cases the experiments had to be discontinued before all of the young had matured, and, since males usually mature more rapidly than females, it is not surprising that a much higher percentage of males, as compared with the percentage of females, resulted than in the other tests.

Since 12 of the 20 reciprocal crossings produced females, it may be argued that the Connecticut and Washington forms are specifically identical. However, as shown later in this paper, preliminary studies of the anatomy of the two forms have failed to corroborate completely the evidence based on the rearing tests. Possibly this should be taken as evidence that the two forms are varietal, instead of being identical species. No difference could be detected in the habits or coloration of the two forms, and certainly they are more closely related than the deciduous-fruit and citrus forms.

FEEDING EXPERIMENTS

A number of feeding experiments were made to determine whether deciduous-fruit mites would thrive on citrus plants and whether the citrus form would thrive on deciduous plants; and, if these questions should be answered affirmatively, whether the characteristic coloration of each form, which will be described later, would be changed by the new food plant. Mites are not necessarily limited in their feeding habits. The two-spotted mite (*Tetranychus bimaculatus*) and the clover mite (*Bryobia pretiosa*) have a rather large list of food plants. The deciduous-fruit mite has been reported by Garman as found on elm in Connecticut, and the junior writer has found it on elm and on the black locust (*Robinia pseudacacia*) at Yakima, Wash., neither tree being related to its favored food plants, which are in the rose family. The citrus mite does not appear to have been authentically recorded from plants other than citrus. In Europe, *Paratetranychus pilosus* has been recorded by Zacher [4] from 29 host plants, including 11 species of Prunus, 3 species of Pyrus, 9 species of Rosa (the foregoing all in the family Rosaceae), and on *Ribes sanguineum* (Saxifragaceae), *Robinia pseudacacia* (Leguminosae), *Vitis vinifera* (Vitaceae), several species of Ulmus (Urticaceae), and a species of Alnus (Betulaceae).

The feeding experiments were conducted both in Washington and in California.

DECIDUOUS-FRUIT MITES ON CITRUS

In the fall of 1924, at Yakima, Wash., 41 newly hatched and day-old deciduous-fruit mites from peach, pear, and apple were placed on green lemons. This was done at various times from August 16 to September 14. Of these, 22, or 54 per cent, lived less than 1 day; 10, or 24 per cent, lived 1 to 2 days; and 9, or 22 per cent, lived 2 to 12 days. Of the latter, 6 reached the protonymphal stage, and the remaining 3 lived until the deutonymphal stage. None matured.

Thirteen deciduous-fruit females from peach and apple were placed on lemons, 5 of them living less than a day, 2 living 1 to 2 days, and 6 living 2 to 9 days. Only 12 eggs were deposited, of which 8 hatched, but none of the young lived more than 2 days. Several attempts were made in 1923 and 1924 to colonize deciduous-fruit mites on the grapefruit seedlings, but without success. Invariably the mites disappeared within a week or so.

On several occasions active stages and eggs of the deciduous-fruit mite were sent from Yakima to Lindsay, Calif., where the senior writer used them in rearing experiments.

On August 3, 1924, living larvae and eggs of the deciduous-fruit form were received at Lindsay and immediately placed on an isolated branch on the south side of a navel orange tree. The eggs continued to hatch, and for a few days larvae and first-stage nymphs were observed on the citrus foliage. All of these died before reaching the second nymphal stage.

On August 10, 1924, a second consignment of material was received from Yakima, and was promptly isolated on a branch on the north side of a vigorous navel orange tree at Lindsay. This lot behaved exactly like the preceding one. Individuals, none of which appeared

[4] Through correspondence with the senior writer.

to be feeding, were seen the first two days moving about on the orange foliage. After an interval of four days no living mites could be found, even by the most critical search.

On September 23, 1924, a colony consisting of a male, a female, and 23 progeny (ova and larvae) was received from Yakima, and these were carefully inclosed within one of the regulation mite-rearing cells attached to an orange tree. The female died September 24, and on the same day 11 ova had hatched and 3 dead larvae were seen. By the 28th one additional egg had hatched, but not a single living mite was present. On the 29th four more ova had hatched, but all active individuals had died. On October 7 one additional egg had hatched and died. On October 14 no more ova had hatched. The weather had been very favorable throughout the rearing period.

On April 8, 1925, a rearing cell was started on a small orange tree, with individuals of the deciduous-fruit mite just received from Yakima. On April 9, six active larvae were present; on the 10th, no larvae had died and no additional eggs had hatched. On the 13th, one larva, one first-stage nymph, and several dead larvae were present; on the 14th, there were one first-stage and one second-stage nymph; on the 15th, all individuals were dead. The temperature had been favorable during the rearing period.

Another rearing cell had been started on April 8, 1925, with Yakima material received that day. Several eggs had hatched by the 9th. By the 10th many eggs had hatched, and all but one larva had died. By the 14th all individuals had died and the colony was extinct.

At the same time that the two last-mentioned cells were started, an apple twig from Yakima, heavily infested with eggs and larvae of the deciduous-fruit mite, was attached to a branch of an orange tree in an orchard at Lindsay. Care had been taken to ring the base of this branch with tanglefoot, and otherwise to isolate it from other parts of the tree. Since this colony existed for about 35 days its daily progress will not be recorded, but the results will be briefly summarized. On April 13 numerous active larvae were seen on the isolated branch, all being on the upper surface of the leaves. On the 14th a few first-stage nymphs had appeared. On the 15th several second-stage nymphs were seen. Many dead individuals were observed on the 16th. A few adult males and females were seen on the 17th. On the 20th a few eggs had been deposited, mostly on the stems of the current year's growth. On the 27th a colony of one female and five eggs was seen. On the 28th another colony, of 35 eggs, was seen. On May 2 this colony consisted of 37 ova and 2 dead larvae. On the 4th several eggs and a few larvae were seen on the isolated branch. On the 13th only five ova could be found and they appeared nonviable. After long search one first-stage nymph was found. On May 22 a most careful search of the isolated orange branch failed to reveal the presence of a solitary individual of the deciduous-fruit mite. No individuals of the second generation seem to have passed the first nymphal stage.

In the course of the rearing tests here recorded no predatory insects or mites were observed. The weather for the most part was very favorable. The death of the colonies should be attributed, it would seem, to inability of the deciduous-fruit mites to adjust themselves to the orange foliage.

The characteristics of the mites reared at Lindsay on citrus agreed with the description of the mites in the Northwest as recorded herein by the junior writer. Furthermore, many eggs were examined and were found to be typical of the eggs of the deciduous-fruit mite, the apical stalk being devoid of any trace of guy fibrils. Obviously the citrus environment had not the slightest effect on the characteristics of any stage of the deciduous-fruit mite.

On June 17, 1926, at Berkeley, Calif., the writers observed a few young mites and eggs on citrus trees on the grounds of the University of California. These trees were within a few feet of apple and plum trees that were heavily infested with the deciduous-fruit mites. After careful observations the writers concluded that the slight infestation on the citrus trees was due to stragglers from the deciduous trees. It was evident that females from the deciduous trees had wandered or been carried to the citrus trees, and that they had deposited eggs there, which had hatched, but that the resulting young were not able to live to maturity. If the deciduous-fruit and citrus forms were identical it would be extremely improbable that the citrus trees in this case would be almost free of the mites when deciduous trees within 10 or 15 feet were very heavily infested.

Poutiers (*14*) mentions finding *Paratetranychus pilosus* on lemon at Mentone, France, but this may be questioned, as it was not stated that the mites were authoritatively determined.

CITRUS MITES ON DECIDUOUS FOLIAGE

Attempts at colonizing citrus mites on deciduous foliage were more successful. On September 8 to 11, 1924, at Yakima, Wash., 81 newly hatched young from lemons were placed in cells on apple foliage. Twenty-six of these, or 32 per cent, lived less than a day; 14, or 17 per cent, lived 1 to 2 days; and 41, or 51 per cent, lived from 2 to 28 days. Twenty of these, or 25 per cent of the total, matured and produced 3 males and 17 females. These females lived from 1 to 26 days, and deposited 40 eggs, none of which hatched, probably on account of the lateness of the season.

On September 23, 15 newly hatched young from lemons were placed in cells on peach foliage. Six of these, or 40 per cent, lived less than 3 days, and 9 lived from 17 to 34 days. Eight of the latter, or 53 per cent of the total, matured and produced females. As this occurred in October the leaves soon dropped, and the length of life of these females was not recorded.

In 1925 further experiments were made at Yakima with larvae from lemons. The larvae were placed in cells on apple, pear, and peach foliage, and records were kept of the number living less than one day, the number living longer but failing to mature, and the number maturing. These records and those obtained in 1924 are shown in Table 8. Parallel records of citrus mites and deciduous-fruit mites on pear and apple are given for purposes of comparison.

These records indicate that the citrus form will live on deciduous foliage as well as will the deciduous-fruit form, at least for the first generation. The high death rate on the first day is largely due to injuries received in the delicate operation of transferring the mites. Of the 30 citrus mites maturing in this experiment 9 were males and 21 were females.

TABLE 8.—*Longevity of larval citrus and deciduous-fruit mites, fed on deciduous foliage at Yakima, Wash., 1924–25*

Food plant	Form	Number of larvæ	Living less than 1 day		Not maturing		Maturing	
			Number	Per cent	Number	Per cent	Number	Per cent
Apple	Citrus	18	5	28	3	17	10	55
Do	Deciduous fruit	37	10	27	4	11	23	62
Pear	Citrus	18	4	22	0	0	14	78
Do	Deciduous fruit	49	13	27	7	14	29	59
Peach	Citrus	13	4	31	3	23	6	46
Do	Deciduous fruit [a]							
Total	Citrus	49	13	27	6	12	30	61
	Deciduous fruit	86	23	27	11	13	52	60

[a] No record.

The 21 citrus females produced on apple, pear, and peach were mated with citrus males, with the exception of two, reared on peach, which were not mated. Records, presented in Table 9, were then kept of the progeny of these females.

TABLE 9.—*Record of second-generation citrus mites, produced on deciduous foliage at Yakima, Wash., in 1925*

Food plant	Cell No.	Number of females in cell	Number of eggs deposited	Number of eggs hatched	Number of young matured
Apple	10	1	0	0	0
Do	11	3	20	(a)	[b] 1
Do	12	1	(a)	3	[c] 1
Do	18	1	5	1	0
Do	19	1	26	8	[b] 4
Pear	13	2	(a)	6	0
Do	14	1	1	1	[c] 1
Do	15	3	(a)	10	0
Do	17	1	(a)	9	0
Do	21	1	16	10	0
Peach	7	1	20	(a)	0
Do	8	2	21	(a)	[b] 1
Do	9	1	8	0	0
Do	16	1	1	0	0
Do	20	1	15	5	[d] 2
Estimated total			200	85	10
Recorded total			133	53	10

[a] Several. [b] Female. [c] Male. [d] 1 male, 1 female.

The junior writer was away from Yakima for a time while these experiments were in progress, and it was therefore not possible in all cases to record the length of life of the females or the exact number of eggs deposited. The maximum number deposited by one female, however, was 26, and the average probably about 10, whereas the average number of eggs deposited by deciduous-fruit females on deciduous foliage at this time of year, as determined at Yakima in 1923 and 1924, was approximately 42. Quayle (*15, p. 489*) states that the average number of eggs deposited by the citrus mites on citrus is about 30. In most cases the number of eggs hatching was recorded. The total number was estimated at 85, or less than 50 per cent of those deposited. This estimate may be high, for in the cases where com-

plete records were obtained 72 eggs were deposited and 25 hatched, or only 35 per cent. Eggs deposited by deciduous-fruit females on deciduous foliage hatch much better. In 1923 and 1924 records were obtained in the months of May and June of 4,226 eggs of the deciduous-fruit mite; of this number 3,383, or 80 per cent, hatched. These eggs were deposited in cells similar to those used to confine the citrus females.

Of the estimated 85 young hatching, only 10 matured, 3 of them being males and 7 females. Of the 53 young actually recorded only 8 matured, or 15 per cent. These data show a very high death rate; much higher than was found in the first generation, where 61 per cent matured, in spite of the fact that the latter were all transferred by hand from one food plant to another, whereas the ones here considered were allowed to remain in the cells in which they were hatched. This death rate is also much higher than occurs with deciduous-fruit mites on deciduous foliage, even when reared for several generations. The continued feeding on deciduous foliage apparently weakens the citrus form.

The seven second-brood citrus females produced on apple and peach foliage were mated, two of them with citrus males and the others with deciduous-fruit males, no more citrus males being available at this time. Two of the seven females were accidentally killed before depositing all their eggs, and the other five died after depositing only 60 eggs, or an average of 12. Twenty of these eggs, or 33 per cent, hatched. Only 3 of the 20 young matured, or 15 per cent. These are approximately the same percentages as obtained for the second-brood eggs. Unfortunately, the three adults were all males. They were the progeny of the matings of citrus females with deciduous-fruit males, the citrus × citrus matings producing no adults. The experiment could therefore be carried no further.

A careful comparison was made of the color of all the citrus mites reared on deciduous foliage. Invariably the color remained characteristic of the citrus form, even to the third generation. This was true of males and females alike, and is considered the most significant part of the feeding experiments. Aside from this, although the citrus form apparently thrives on deciduous foliage during the first generation, it seems to become somewhat weakened, for in succeeding generations a much smaller number of eggs are deposited, a much smaller number hatch, and fewer larvae mature, than is the case with deciduous-fruit mites on deciduous foliage.

In order to show that continued rearing in cells does not materially reduce the oviposition capacity of the females, Table 10 is presented. This table records all of the cases in 1924 where a complete record was obtained of the number of eggs deposited in rearing cells by direct progeny of first-brood mites through four to six generations. Each case represents the number of eggs deposited by a single female in each generation. The high rate of oviposition in the second generation was very noticeable, and is believed to be due to specially favorable weather conditions. These eggs were laid in May and June, just when the citrus mites were being reared, and yet the latter showed no such rate of oviposition. Hot weather later reduced the oviposition rate of the deciduous-fruit females.

TABLE 10.—*Records of oviposition of deciduous-fruit mites on deciduous foliage, reared through succeeding generations, at Yakima, Wash., in 1924*

No.	Number of eggs deposited by—					
	First generation	Second generation	Third generation	Fourth generation	Fifth generation	Sixth generation
1	30	* 5	59	* 20	42	
2	34	87	* 36	10	* 17	
3	84	52	* 22	43	49	50
4	84	52	* 22	35	* 21	
5	30	91	* 35	35	* 24	
6	46	62	31	33	* 28	
7	46	62	* 33	32	* 14	
8	* 14	73	40	* 22		
Average, including incomplete colonies	46	61	35	29	28	

* Female was accidentally killed, or escaped, before completing oviposition.

The percentage of eggs hatching is also apparently reduced to some extent by hot weather and increases again in the fall, as shown in Table 11, but in no case is it as low as that of eggs deposited by citrus females reared on deciduous foliage.

TABLE 11.—*Records of hatching of succeeding generations of eggs of the deciduous-fruit mite on deciduous foliage, at Yakima, Wash., in 1924*

Generation of females depositing eggs	Month in which eggs were laid	Number of eggs laid	Number of eggs hatched	Percentage hatched
First	May	1,120	955	85
Second	May–June	1,547	1,246	81
Third	June–July	1,152	745	65
Fourth	July–August	674	494	73
Fifth	August–September	662	587	89

As already mentioned, red spiders of several species are known to have various food plants, and it is not surprising that the citrus form should be able to develop for a time on deciduous foliage. Essig (*5*) mentions sending to Garman, for comparison with the Connecticut form, mites that were taken on almond and citrus trees at Berkeley. Essig does not mention any difference in their appearance, and it is possible that all the mites he collected were of one form, especially if two kinds of host plants were growing near each other. It is also possible that two species were represented, and that the gross characters—i. e., coloration, body outline, and the like—were obliterated in mounting, and the specific differences overlooked in the ultimate examination.

COLORATION

The coloration of the deciduous-fruit form is quite distinct from that of the citrus form. The body of the deciduous-fruit female is colored a brownish red. The tubercles and hairs are whitish, contrasting strongly with the body color. (Fig. 1, A.) Citrus females feeding on lemon fruit, where they do not get much chlorophyll, are colored a bright red—almost vermilion. Those feeding on foliage are

darker, owing to the influence of chlorophyll, the color being a velvety, purplish red. The tubercles of the citrus form are invariably of about the same color as the body, and the hairs are light reddish, there being little or no contrast between these and the body.

The deciduous-fruit males are greenish in color, the anterior and posterior ends being fulvous; with age the color changes to orange. The citrus males are dark red (bright red on lemons), the anterior and posterior ends being somewhat lighter. As already mentioned, citrus mites fed on deciduous foliage from the time of hatching retained their characteristic coloration, and the adults that matured, even in the second generations, were indistinguishable from citrus mites reared on citrus foliage. Deciduous-fruit mites fed on citrus foliage also retained the color native to the deciduous-fruit form. The males that resulted from crosses of deciduous-fruit and citrus mites invariably bore the color of males of the form to which their female parent belonged. It is thus evident that the difference in

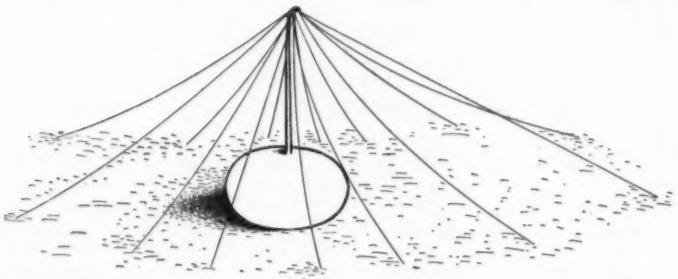

FIG. 2.—Egg of citrus red mite. Method of attachment to leaf is shown. (After Woodworth)

color, as between the two forms, is not the result of feeding on different food plants.[5]

OVIPOSITION

The egg of the citrus mite (fig. 2) has been described and illustrated by Woodworth (*18*), Quayle (*15*), and McGregor (*11*), as having webbing or guy fibrils radiating from the egg stalk. The junior writer has never been able to find these guy fibrils on eggs of the deciduous-fruit form, and they are not mentioned in Garman's description of the egg (*8*). Essig (*5*) found the webbing on eggs deposited on lemon leaves in California, but considers it "more or less haphazard and due to the number of mites walking over the eggs and the freedom from external influences," although Woodworth and Quayle had previously described the placing of these fibrils by the citrus females.

The junior writer was fortunate in being able to observe several times the act of oviposition by the citrus mite. On September 12, 1924, a citrus female was found ovipositing. As soon as the egg was deposited, the abdomen was gradually elevated until the egg stalk was formed. The female then turned around, applied her

[5] Basing his judgment on a very intimate knowledge of the citrus mite in Florida, and on previous publications on *Paratetranychus pilosus*, W. W. Yothers, of the Bureau of Entomology, at Orlando, Fla., has always maintained that the two species are distinct. After a very extended trip through the Pacific coastal region he wrote to the authors as follows: "While at Yakima, Mr. Newcomer showed me the species *P. pilosus*. It was very evident to an entomologist with a farmer's mind that this was not the same species as *citri*. After seeing both species, to me it seems inexcusable that anyone should call them the same pest."

mouth parts to the tip of the egg stalk, and attached a thread to it, apparently by rubbing the mouth parts across the end of the stalk. The mouth parts were then moved down to the leaf at one side of the egg, and the thread attached. This performance was repeated ten or a dozen times, each alternate thread usually being attached to the leaf on the side opposite to the point of attachment of the one just before it.

On September 20 another female was observed to deposit an egg, and only five guy fibrils were placed. On November 7 a third observation was made. In this case the female had placed but two fibrils when she was interrupted by the attentions of a male that happened along. The female ran away, but soon returned, and placed eight more fibrils. This action indicates a definite instinct on the part of the citrus female to attach these supports. On November 20 another observation was made, when the female placed six guy fibrils on the egg stalk.

Oviposition by deciduous-fruit females has been observed many times by the junior writer and by M. A. Yothers, of the Yakima laboratory. These females have never been seen to place guy fibrils on their eggs. The process of oviposition is much like that of the citrus form, except that as soon as the egg stalk is made the female runs away and begins feeding, and pays no more attention to the egg. A large number of deciduous-fruit mite eggs have been examined with compound and binocular microscopes in a strong light, and no evidence of these guy fibrils has been found. Occasionally a few strands of webbing would lie upon the egg stalk, but these were evidently made accidentally by other mites that happened to run over the eggs. Although guy fibrils are normally deposited by the citrus females, it is possible that these females do not always place them, and it is also likely that they may become removed when mites or insects run over the eggs; certainly a lack of them is not normal.

The citrus mite apparently does not deposit "winter eggs," as its food plants are in foliage the year around, and the climate in the citrus-growing region is mild enough to enable the mites to develop throughout the year. The deciduous-fruit form, on the other hand, must hibernate because its food plants are without leaves in winter. It does this by depositing "winter eggs" on the twigs, late in the summer. These eggs are slightly larger than the summer eggs, and have a thicker shell. The citrus mites reared on deciduous foliage at Yakima in the fall of 1924 showed no evidence of depositing this special type of egg. The eggs deposited all died on account of cold weather.

ANATOMY AND TAXONOMY

Concerning the taxonomic status of the American species of Paratetranychus, as based on anatomy, there has been considerable argument in the past. The structures of these mites on which species depend are so ultraminute that actually the question becomes largely a matter of keen eyesight supplemented by a large degree of patience and an ample supply of material. A further handicap in the clarification of the issue is to be found in certain discrepancies and confusion existing in the European literature on the subject.

The original description of *Tetranychus* (*Paratetranychus*) *pilosus* by Canestrini and Fanzago, published 40 years ago, is so brief that it contains little of value to present-day taxonomists.

In 1917 Banks (*2*) attempted to replace Zacher's generic name Paratetranychus with Oligonychus of Berlese. In this, Banks seems to have been unjustified, and the writers agree with Zacher (*20, p. 91*), who presents the facts as follows (translation):

> Banks recently designated my genus *Paratetranychus* as a synonym of *Oligonychus* Berlese. I can not agree with this view, since Berlese clearly referred the type species of my genus (*P. pilosus* C. and F.) not to *Oligonychus*, but to *Tetranychus*, and cited specifically *O. brevipodus* Targ.-Tozz. as the one species of *Oligonychus*. From the brief characters of the genus *Oligonychus* very little is to be learned as to whether they agree with the vital characters of *Paratetranychus*, namely, the presence of a claw with empodial appendages shorter than the claw; and with a collar-trachea that is straight and with a bladder-like enlargement at its end. *Oligonychus* appears rather to correspond to *Neotetranychus* Träg. Therefore I hold fast to the designation of *Paratetranychus* for the native species *pilosus* C. and F. and *ununguis* Jac.

As already pointed out, Essig (*5*) in 1922 attempted to replace *Paratetranychus citri* McG. by *P. pilosus* Can. and Fanz., having been convinced by Garman's and Ewing's diagnoses that both the red mite of the Northwest and the citrus mite of Florida and California were none other than the European red mite. In reaching this conclusion these workers have ignored certain rather evident facts, previously published. In 1915 Trägårdh (*17*), of Sweden, presented a very detailed account of some of the European tetranychids, accompanied by many rather careful drawings. Among other characters, the structure of the tarsal appendages, the collar trachea, and the penis of *P. pilosus* were presented quite clearly. In addition, Zacher, of Germany, on repeated occasions has published critically on the red spiders of Europe. On most of the anatomical features of *P. pilosus* these two authorities are agreed. This is true of the gross body characters, the palpi, the collar, trachea, and the tarsal structure. They disagree on the outline of the penis.

In connection with the present studies the senior writer has had considerable correspondence with Zacher, who has furnished material of *Paratetranychus pilosus*, and in addition has personally contributed drawings and detailed descriptions. Through the material sent by Zacher from Berlin, Germany, the writers have been able to make a study of the European red mite on apple and on elm. In most respects they have been able to corroborate the published statements of Zacher and of Trägårdh. Unfortunately no males were included in the material from Germany, and it has been impossible to check on the alleged character of the penis of *pilosus*.

At the outset it may be well to state that extended study of the tetranychids has established the fact that, for any given species, most specific characters are somewhat variable. This is true of the palpus, tarsus, penis, collar trachea, and other structures. Of the characters used taxonomically, probably the penis varies least and the tarsus most.

The European authorities seem agreed that the tarsal claw of *Paratetranychus pilosus* possesses only four appendiculate spurs. The writers' studies of European material have revealed that cases occur of tarsi having from four to six spurs, but with the four-spurred claw seemingly typical. In the case of both the citrus mite and the

deciduous-fruit mite of the Northwest the tarsal claw possesses typically six appendiculate spurs.

The collar trachea of *Paratetranychus pilosus* extends ventrad from the middorsal pore as a comparatively short and straight tube, ending abruptly in a semispherical chamber. The collar trachea of both *P. citri* and the northwestern mite is distinctly undulating, somewhat longer, and often terminates in a chamber which is merely a slight enlargement of the tube.

Zacher (*19*) mentions, and Trägårdh (*17, p. 27*) and Hirst (*10, p. 59*) picture, in the female, the terminal "finger" of the palpal "thumb" of *pilosus* as distinctly spatulate—almost as thick as long. In this character the deciduous mite of the Northwest conforms rather closely. The terminal palpal "finger" of *citri* is not strongly spatulate and is decidedly longer than thick.

Concerning the penis structure of *pilosus*, Trägårdh and Hirst agree fairly closely, but the delineation of this organ by Zacher shows certain discrepancies. Trägårdh (*17, p. 27*) and Hirst (*10, p. 51*) figure for the penis the following characters: A dorsally situated obtuse basilar lobe; shaft narrowed posteriorly and bent upward to form the tapering hook, which is pointed terminally. A drawing of the penis of *pilosus* by Zacher, made especially for the writers, shows no projection at the usual position of the basilar lobe, but has a dome-like swelling ventrally at a point opposite the usual location of the basilar lobe. (It has been suggested that Zacher's preparations were distorted by treatment with caustic soda.) The *pilosus* type of penis (of Trägårdh and of Hirst) superficially resembles that of *citri* and of the deciduous-fruit form of the Northwest, but both of the American species exhibit penis features which are seemingly distinct. The penis in each case has an acutely pointed basilar lobe, and the distal half of the hook is more acuminate than in *pilosus*. The chief difference between the penis of *citri* and that of the northwestern form lies in the fact that in the former the shaft is shorter than the thickness in the region of the basilar lobe, whereas in the case of the deciduous-fruit form the shaft is longer than the thickness at the basilar lobe.

In the matter of the relative length of the joints of the foreleg, there again seems to be a difference between *pilosus* and the deciduous-fruit form of the Northwest. In the latter the length of the femur equals that of the tarsus; in *pilosus* the length of the tarsus exceeds that of the femur by nearly one-fourth of the latter; in the case of the citrus mite of southern California the reverse seems to be the case, the femur somewhat exceeding the tarsus in length.

It is doubtful if, in most cases, the mandibular plate should be accorded much taxonomic importance. Both emarginate and non-emarginate cases occur in both *pilosus* and *citri*. The latter has a mandibular plate that usually, as a type, has a slight emargination anteriorly; the former is generally without a trace of emargination.

All that should be necessary to dispel any remaining doubt as to the specific distinction between the deciduous-fruit red mite and the citrus mite of America is the very different structure of the eggs of the two species. At different times in the literature, since the first careful description of the citrus mite and its egg, various workers have detailed the unusual structure of the latter. The egg of the

citrus mite is subspherical, being noticeably flattened vertically, and is red in color. From the dorsal "pole" of the egg there arises a stalk which in position is coincident with the continuation of the axis of the egg. The stalk is relatively stout and in length is about twice the vertical diameter of the egg. As a normal feature of oviposition, the female attaches a series of guy fibrils which radiate downward from the tip of the stalk to the supporting leaf surface. (See fig. 2.)

The structure of the egg of the deciduous-fruit red mite of the Northwest is quite different from that of the citrus mite. In outline the egg is spherolenticular, even more flattened than in the case of the egg of the citrus mite, and is red in color. The apical stalk is present, but only slightly longer than the axial diameter of the egg; rarely coincident with the continuation of its axis, being deflected and bent at various angles, and relatively weak. The junior writer has observed many cases of oviposition by the deciduous-fruit mite, but has never seen the formation of guy fibrils, and has no evidence of their existence in this species.

The various writers who have described the egg of the Paratetranychus of the eastern part of the United States have failed to mention the presence of the guy fibrils on the axial stalk. Garman (*8, 9*) published a good figure of the egg, which is devoid of guys. This would suggest an affinity with the northwestern deciduous-fruit mite, but other characters, such as the tarsus and penis, indicate an even closer relationship with the true European form. Certainly the mite of Connecticut is entirely distinct from *Paratetranychus citri* McG.

The egg of *Paratetranychus pilosus* is described by Trägårdh roughly as follows: Roundish; 29 μ in diameter, with a short shaft on its under side by means of which it is attached to the supporting plant surface; a groove surrounds the base of the shaft; color yellowish. (Trägårdh does not claim the presence of a dorsal axial stalk.)

DESCRIPTION OF PARATETRANYCHUS PILOSUS CAN. AND FANZ.

(Fig. 3)

Length of female 0.315 mm.; color rather uniformly reddish-brown; dorsal bristles stout, pilose, arising from prominent tubercles, the hairs and tubercles of about the same color as the general body color (according to one authority, the bristles arise from whitish tubercles); eye cornea removed from subfrontal bristle a distance about equal to interval between latter and frontal bristle; mandibular plate not emarginate anteriorly; terminal "finger" of palpal "thumb" strongly spatulate, about as wide as long; tarsal joint of foreleg exceeding in length the femur by nearly one-fourth the latter's length; tarsal claw sickle-shaped, nearly as thick at mid-point as at base; at a point not much proximad of the mid-point four appendiculate spurs arise which in length somewhat surpass the claw; collar trachea nearly straight and of even caliber, with spherical dilated terminal chamber; ovum (according to Trägårdh) yellowish, roundish, with a short shaft on its under side by means of which it is attached to plant surface, with a groove around base of shaft; (according to Zacher) red, with a dorsal apical stalk (no mention in the literature of guy fibrils). Penis of male relatively long, with obtuse basilar lobe, shaft nearly half as long as inner lobe, hook bent only 45° from the main axis of penis (according to Zacher, no basilar lobe, but with dome-shaped swelling ventrally). Particularly a pest of fruit trees of the family Rosaceae.

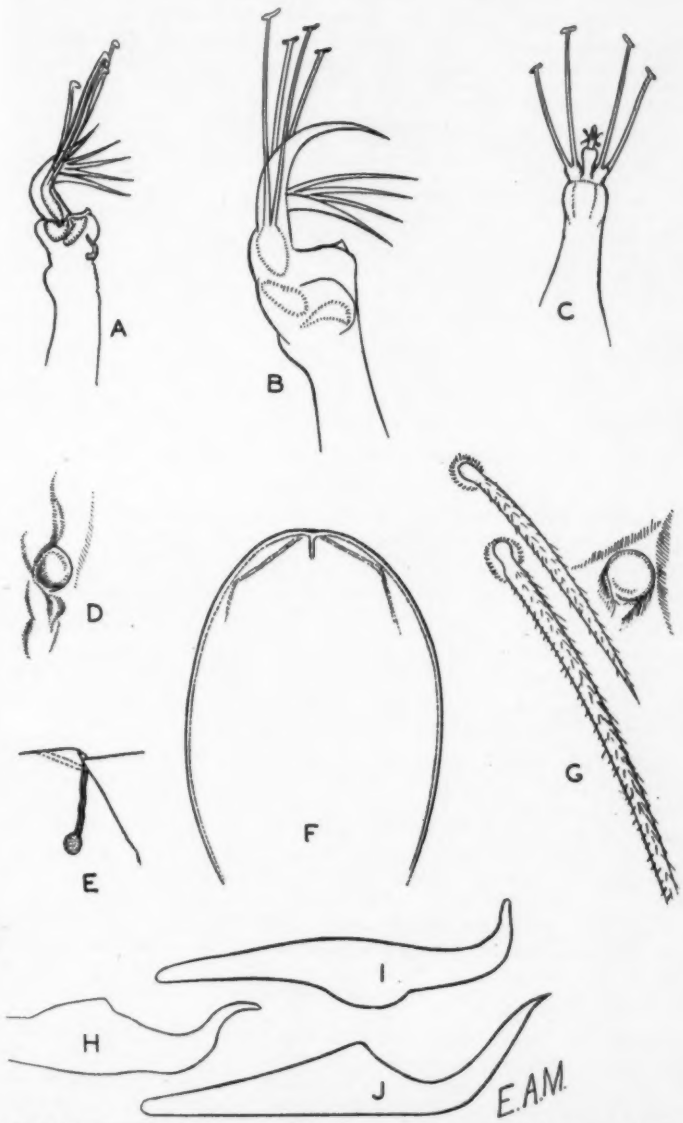

FIG. 3.—*Paratetranychus pilosus:* A, Tarsal appendages viewed in profile (alcoholic material from Berlin, Germany, on apple); B, tarsal appendages viewed in profile (mounted material from Berlin, Germany, on elm); C, tarsal appendages viewed ventrally; D, eye cornea viewed from above; E, collar trachea; F, mandibular plate; G, frontal and subfrontal bristles and eye cornea of right side viewed from above; H, I, J, penis. E and J, after Trägårdh; H, after Zacher

DESCRIPTION OF PARATETRANYCHUS CITRI McG.

(Figs. 4 and 5)

Length of female 0.305 mm.; color a velvety purplish red, with dorsal tubercles of almost the same color, and with bristles light reddish (tubercles occasionally a little paler than body color); eye cornea about twice as far behind the subfrontal bristle as the latter's distance from the frontal bristle; mandibular plate typically with an inconspicuous emargination anteriorly; terminal "finger" of palpal "thumb" not strongly spatulate, decidedly longer than thick; legs paler than body color; femur somewhat exceeding in length the tarsus; tarsal claw rather straight for two-thirds of its length and then bent sharply downward, noticeably thickest at base, with six appendiculate spurs arising at a point one-third the length of the claw from its base—their tips extending well beyond that of the claw; collar trachea relatively long, undulating, and terminating in a chamber which is often merely a slight enlargement of the tube; ova subspherical, noticeably compressed vertically; at first pale, later turning bright red; the egg bears dorsally an apical stalk which coincides with the continuation of the vertical axis, relatively stout, in length about twice the vertical diameter of egg; normally with a series of guy fibrils radiating from tip of stalk to supporting leaf surface. The color of the male is bright red to dark red, depending somewhat on food plant, the anterior and posterior aspects being somewhat lighter. Penis relatively short, with acute basilar lobe; shaft only about one-third as long as inner lobe, shorter than thickness of penis in region of basilar lobe; hook bent almost 60° from main axis of penis. Almost exclusively a pest of citrus trees.

DESCRIPTION OF NORTHWESTERN DECIDUOUS MITE

(Fig. 6)

It may be well at this point to record the chief features wherein the deciduous-fruit Paratetranychus of the Northwest appears to differ from typical material of *P. pilosus*. These are as follows:

Body color usually garnet-red, dorsal tubercles and bristles whitish; foreleg with femur equaling tarsus; tarsal claw typically possessing six appendiculate spurs; collar trachea often undulating and with terminal chamber elliptical; egg spherolenticular, red, usually with a weak axial stalk slightly longer than vertical diameter of eggs, usually deflected at an angle from the axis of ovum. The color of the male is at first greenish, changing to brick-red or orange; the anterior one-third and posterior tip of body pale pink or fulvous; penis with well developed acute basilar lobe; very sharply acuminate at tip.

Zacher (*19*) mentions a Paratetranychus of a dark cinnamon-brown color with whitish tubercles, occurring in Germany on gooseberry, and, according to Berlese, on pear in Italy. The claw possesses four spurs which are about one and one-half times as long as itself. The penis is broadened spoonlike toward the end, and with a prominent lobe on one side. This he designates as *P. pilosus* var. *albogut-tatus*. The coloration of this form considerably resembles the northwestern deciduous-fruit mite, but the other characters, as described by Zacher, are entirely aberrant from the northwestern form.

CONCLUSIONS

The writers have concluded that the citrus mite (*Paratetranychus citri* McG.) and the European red mite (*P. pilosus* Can. & Fanz.) are entirely distinct species. Practically all the evidence at hand favors this conclusion. It is also concluded that the citrus mite is distinct from the deciduous-fruit forms of Paratetranychus found in the United States.

The only evidence indicating that the deciduous-fruit and citrus forms are not more than races of one species is the fact that they are rather similar in general appearance and have similar habits. In

dealing with creatures as small as these one must not be misled by such relatively superficial similarities, but must compare the forms more minutely, both anatomically and biologically. The writers

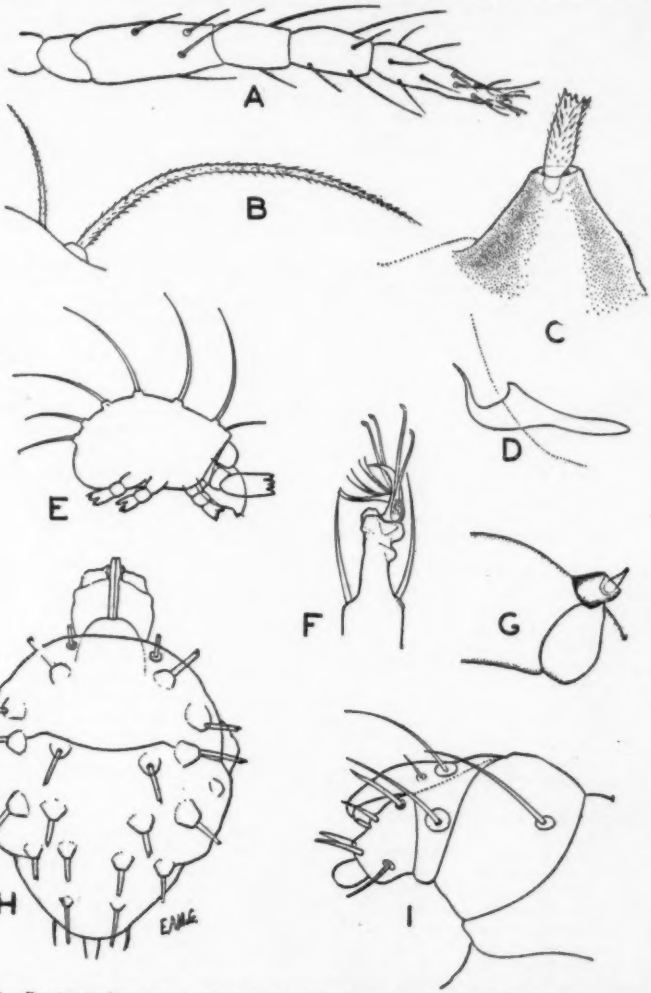

FIG. 4.—*Paratetranychus citri:* A, Right foreleg (dorsal); B, frontal and subfrontal bristles; C, attachment of dorsal bristles to tubercle; D, penis; E, profile view of female (only proximal portion of legs shown); F, tip of tarsus, with appendages; G, section of palpus of male, showing tubercled spur; H, dorsal outline of male, showing distribution of dorsal bristles (the latter amputated); I, left palpus of female (outer view), showing "thumb" claw, and other appendages. Drawn from material from Florida

know from experience that entomologists who have not made a careful study of the biology of mites may very easily arrive at wrong conclusions about them, and it is therefore not at all surprising that such conclusions have been published.

It is believed that the following points give ample evidence that the citrus and deciduous-fruit forms are distinct species.

1. *Anatomical differences.*—Characteristics of *Paratetranychus citri* are: Tarsal "thumb" with terminal "finger" not strongly spatulate, decidedly longer than thick; collar trachea relatively long; femur of foreleg somewhat exceeding the tarsus in length; tarsal claw with proximal two-thirds of length rather straight, noticeably thickest at base; shaft of penis shorter than width in region of basilar lobe; egg subspherical, apical stalk coincident with axis of ovum, relatively stout, about twice the vertical diameter of egg, normally with a series of guy fibrils extending from tip to supporting leaf.

Characteristics of *Paratetranychus pilosus* are: Tarsal "thumb" with terminal "finger" distinctly spatulate, almost as thick as long; collar trachea relatively short; femur of foreleg equaling the tarsus in length; tarsal claw sickle-shaped, about as thick at mid-point as at base; shaft of penis longer than thickness at basilar lobe; egg spherolenticular, apical stalk relatively weak, deflected at various angles from axis of egg, slightly longer than axial diameter of egg, guy fibrils not present.

2. *Failure to interbreed.*—Experiments made by the writers have shown that the progeny of females of either form, when crossed with males of the other form, are invariably all males. Since this occurs when females are not impregnated, it is evident that these males are produced parthenogenetically, and that no fertilization has taken place.

FIG. 5.—Collar trachea of *Paratetranychus citri*. Drawn from material from southern California

3. *Failure to thrive on alien food plants.*—The deciduous-fruit mite does not thrive on citrus fruit or foliage, and the writers' attempts to rear it on this food were failures. The citrus form thrives rather well on deciduous foliage for the first generation, but succeeding generations become weakened, depositing only a few eggs, which do not hatch well and the young from which seldom mature. The characteristic coloration of the citrus form is retained, even after two or three generations of feeding on deciduous foliage.

4. *Difference in coloration.*—In color the female of the citrus form is rather uniform purplish red, with concolorous tubercles, and the deciduous-fruit female is a brownish red with discolorous, whitish tubercles. The citrus male is dark red, and the deciduous-fruit male is greenish, turning to orange as it ages. Changing of the food plant fails to alter the respective colors of the two mites. Males resulting from crossing the two forms retain the characteristic color of males of the form to which their female parent belonged.

5. *Different oviposition habits.*—The citrus females deliberately attach their eggs with numerous guy fibrils, radiating from the egg stalk to the leaf. The deciduous-fruit females never do this. The latter deposit "winter" eggs in the fall, whereas the former do not, even under similar conditions.

6. *Different habitat.*—Finally, the habitats of the citrus and deciduous-fruit forms do not overlap. The deciduous-fruit form has not been recorded south of latitude 37° N., either in Europe or America. On the other hand, the citrus form does not seem to occur north of latitude 34° or 35° N. In California, the deciduous-fruit form has not been found south of the San Francisco Bay region, and the citrus form does not occur north of the Tehachapi Mountains. This distribution leaves a gap of about 250 miles. This gap is not caused by lack of host plants, for citrus trees are grown commercially north of Sacramento, often in close proximity to deciduous fruit trees, and various deciduous fruits are grown commercially in or bordering the citrus districts of southern California. The two host plants thus overlap.

On the Atlantic coast, the deciduous-fruit mite has not been recorded south of Charlottesville, Va. (lat. 38° N.), while the citrus mite does not seem to have been recorded north of Florida, there being a gap of about 500 miles between these limits. Deciduous fruit trees are grown in Georgia and in Florida, and to some extent overlap the range of the citrus trees.

In the foregoing discussion of the anatomy and biology of the American species of Paratetranychus it is felt that strong evidence has been presented contributing to the solution of their taxonomic status. The writers prefer to abstain from including the several European species of Paratetranychus in the treatment set forth here.

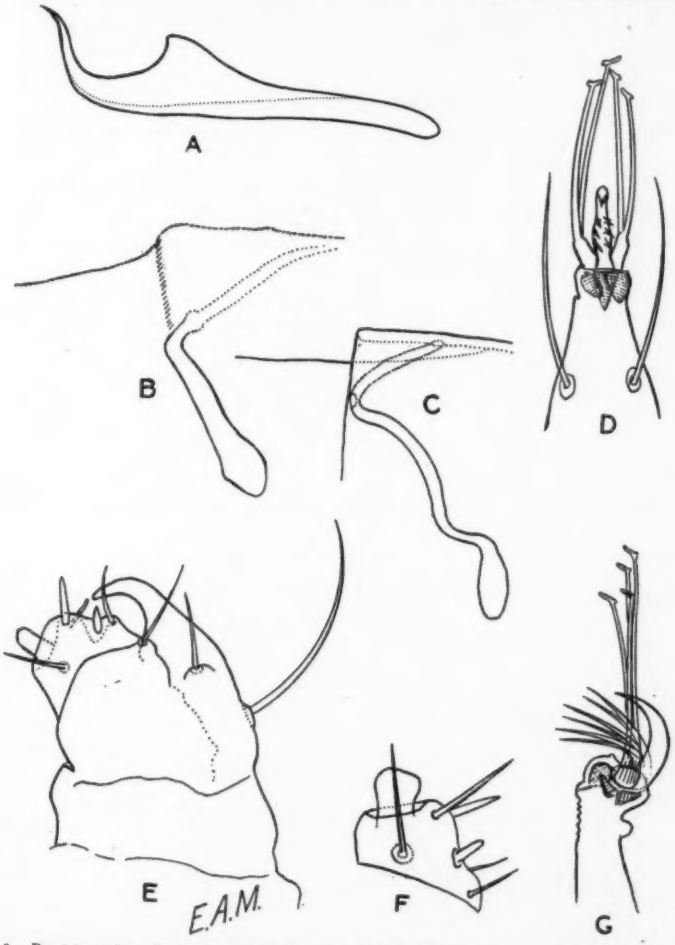

FIG. 6.—*Paratetranychus pilosus* var. *occidentalis:* A, Penis; B, collar trachea; C, collar trachea; D, tarsal appendages, viewed ventrally; E, male palpus and its appendages; F, female palpus and its appendages; G, tarsal appendage in profile. B, Drawn from material from Portland, Oreg.; the other figures drawn from material from Yakima, Wash.

When all the facts are considered, however, it appears that the closest American ally to *P. pilosus* Can. and Fanz. is to be found in the Atlantic coast deciduous-fruit species. The tarsus, penis, collar trachea, and ovum characters of the two latter species seem to agree very closely, and both species appear to feed chiefly on woody species

of the Rosaceae. In comparing the Atlantic species with the red mite of the Northwest, the writers have noted that the evidence is inconsistent; the anatomical characters fail to agree,[6] whereas the rearing experiments suggest that they may be identical.[7] Possibly, for the present, it is best to call the Atlantic species *P. pilosus*, and to designate the deciduous-fruit mite of the Northwest as *P. pilosus* var. *occidentalis*. The complete nonidentity of the citrus and the deciduous-fruit species has been convincingly demonstrated.

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[6] This statement is based largely on drawings and descriptions by eastern workers.

[7] In response to an inquiry, Burlingame, geneticist at Stanford University, has expressed the following opinion: "If two supposed species can be crossed with some success, they might still be considered as belonging to different species, provided there were other good reasons of convenience for so considering them." He cites the fact that the American bison and the domestic cattle have been successfully crossed. The young from this cross were then bred back to the cow, and the progeny of this latter cross will breed among themselves. The cow and the bison are even placed in different genera by the systematists, and, although they were made to breed together, no one would attempt to place them in the same species. Burlingame adds: "If two supposed species will not cross successfully there is good reason for saying that they are different species."

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CHEMICAL CHANGES IN DUSTING MIXTURES OF SULPHUR, LEAD ARSENATE, AND LIME DURING STORAGE [1]

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INTRODUCTION

Since dusting for the control of insects and fungous diseases became a commercial practice it has been usual to combine the insecticide and the fungicide in one mixture, and from the economic standpoint this has been a practical necessity. Such a combination is, of course, impossible unless the materials to be mixed are compatible. That is, they must not react with one another in such a manner as to reduce materially either the insecticidal or the fungicidal value of the ingredients, and, in addition, such combination must not increase the danger of injury to the plant to which it is applied.

Compatibility is a relative term and is usually dependent upon a time factor. A combination which is perfectly compatible under experimental conditions, where the ingredients are combined shortly before being used, may prove incompatible under conditions of commercial manufacture.

Under commercial conditions the materials must be combined considerably in advance of an anticipated demand, as most orders are for immediate delivery. This very often results in a surplus over the needs for the current year, which must either be used up the following year or become a complete loss.

The grower, too, must purchase in advance of his needs and often has a considerable quantity left at the end of the season, which he keeps until the next year.

Under such conditions a combined insecticide and fungicide has from several weeks to a year or more in which to react. Very little information has been made available thus far concerning the effects of such long storage, and for this reason the present investigation was undertaken to determine the nature and extent of such changes and their probable effect upon the insecticidal and fungicidal value of the dust.

THE DUST OF SULPHUR, LEAD ARSENATE, AND LIME

The particular dust dealt with in this article is the 80–5–15, commonly used for the control of insects and diseases on peaches (*10*).[2] It has the following composition:

	Per cent
Sulphur flour	80
Acid lead arsenate	5
Hydrated lime	15

[1] Received for publication Nov. 16, 1927; issued March, 1928.

[2] Reference is made by number (italic) to "Literature cited," p. 191.

The specifications for these ingredients are as follows:

Sulphur: Superfine sulphur flour, 95 per cent passing through a 200-mesh sieve.

Lead arsenate: Standard lead arsenate containing at least 30 per cent arsenic pentoxide, with metallic arsenic in water-soluble form not exceeding 0.75 per cent.

Lime: Hydrated lime of high calcium content analyzing over 90 per cent calcium hydroxide.

PURPOSE OF VARIOUS INGREDIENTS

Sulphur is used for the control of fungous diseases attacking fruit. Lead arsenate is used as a general insecticide for the control of chewing-insect pests. Lime is added for the following purposes (*4*, *5*): (1) To improve the physical properties of the dust by eliminating lumping; (2) to make the dust more fluid, so that it is discharged much more uniformly from the duster; (3) to reduce the cost of the material by displacing sulphur; (4) to reduce the arsenical injury to the plant to which it is applied.

PHYSICAL CHANGES OF MIXTURE DURING STORAGE

The correct quantities of the three ingredients are put into a revolving drum fitted with baffle plates, and thoroughly mixed. The mixture is then weighed into paper-lined burlap bags and stored in this form till sold. Within a month, and sometimes within two weeks, from the time it is mixed the color of the dust has changed from a light yellow to a light gray. Upon longer storage this shade may deepen to a dark gray or black. One-year-old dusts obtained from various manufacturers and farmers differed greatly in shade, ranging from light gray to black. As a rule, with few exceptions, a dust which has reached only the light-to-dark-gray stage within a year does not darken further during the succeeding year's storage. Whereas a fresh dust is very fluid and quite finely divided, a 1-year-old dust has lost much of its fluidity and is more or less lumpy, thus being less efficient for dusting purposes.

PLAN OF INVESTIGATION

The investigation of these changes was carried out along the following lines: (1) Qualitative tests upon old and new dusts to determine what changes had taken place; (2) quantitative analyses to determine the extent and, as far as possible, the mechanism of such changes; (3) probable effect of such changes upon the insecticidal and fungicidal value of the dust; (4) field spraying tests with various compounds formed during storage to determine what effect these would have upon arsenical injury to plants.

QUALITATIVE TESTS

These analyses were made according to the methods of Hinrichs (*8*), and the results were checked by the methods of Chamot (*3*). The results obtained are given below.

NEW DUSTS.—Contained no sulphides or sulphites and only small quantities of carbonates.

OLD DUSTS.—The gray to black shade was due to varying quantities of lead sulphide formed. Small quantities of sulphites and large quantities of carbonates were present also.

QUANTITATIVE TESTS

The analytical methods that were employed are described below.

TOTAL AND WATER-SOLUBLE ARSENIC.—The official methods adopted by the Association of Official Agricultural Chemists (*1*) were used.

SULPHITES.—The modification of the official method of the Association of Official Agricultural Chemists (*1*) described below was used.

Place 15 gm. of the dust in a 500 c. c. distilling flask. Add 5 c. c. of alcohol and 20 c. c. of water. Mix thoroughly to wet the dust. Add an additional 200 c. c. of water. Expel the air from the apparatus with carbon dioxide, add 25 c. c. of 20 per cent glacial phosphoric acid, and distill in a constant current of carbon dioxide until 100 c. c. has passed over. Collect the distillate in 200 c. c. of nearly saturated bromine water, allowing the tip of the condenser to dip below the surface.

Boil the distillate to remove excess bromine; acidify with hydrochloric acid and again bring to boil. Then add an excess of 10 per cent barium chloride and boil for a few minutes. Cover with a watch glass and allow to stand overnight.

Filter through a weighed Gooch crucible; wash with hot water. Ignite to dull red heat and weigh as barium sulphate. Express as calcium sulphite.

SULPHIDES.—Place 15 gm. of the dust in a 500 c. c. distilling flask. Add 5 c. c. of alcohol and 20 c. c. of water and mix to wet the dust. Add an additional 200 c. c. of water. Allow tip of condenser to dip below the surface of 100 c. c. of 20 per cent sodium hydroxide in a beaker. Add 30 c. c. of concentrated hydrochloric acid to the dust in the distilling flask by means of a dropping funnel. Heat gently until the dark color is completely removed from the dust. Continue heating gently for 15 minutes. Sweep out apparatus with a current of carbon dioxide.

Oxidize sulphides and sulphites in distillate to sulphates by adding 5 gm. of sodium peroxide and boiling for 10 minutes. Acidify with cencentrated hydrochloric acid and boil for a few minutes. Add an excess of 10 per cent barium chloride, boil again for a few minutes, and allow to stand overnight. Filter through a weighed Gooch crucible; ignite at a dull red heat and weigh as barium sulphate. Subtract from this the quantity due to sulphites. Calculate as lead sulphide.

CARBONATES.—Distill over, as in the case of sulphides, into 100 c. c. of 20 per cent sodium hydroxide. Sweep out apparatus with carbon-dioxide-free air. Transfer distillate to hot plate. Add 5 gm. of sodium peroxide and boil for 10 minutes to convert the sulphides and sulphites into sulphates. Remove, place in a 500 c. c. Erlenmeyer flask, and carry out the determination according to the official method for the determination of carbon dioxide in Bordeaux mixture (*1*).

HYDROGEN-ION CONCENTRATION.—Shake 1 gm. of dust for one minute with 10 c. c. of previously boiled and cooled distilled water. Allow to stand for 10 minutes. Filter and determine P_H by colorimetric method.

The results of the tests are given in Tables 1 to 5.

TABLE 1.—*Water-soluble arsenic in sulphur-lead-arsenate-lime dusts of various ages*

Sample No.	Water-soluble arsenic pentoxide as per centage of total arsenic oxide		
	Fresh sample	1 year old	2 years old
	Per cent	*Per cent*	*Per cent*
1		1.20	1.20
2	1.16	4.06	
3		2.30	2.33
4	.55	1.00	
5		2.46	2.46

TABLE 2.—*Sulphite content in sulphur-lead-arsenate-lime dusts of various ages*

Sample No.	Sulphite present (as calcium sulphite) per 15 gm. of dust		
	Fresh sample	1 year old	2 years old
		Gram	*Gram*
1	None.	0.0562	
2		.5300	0.531

TABLE 3.—*Sulphide content in sulphur-lead-arsenate-lime dusts of various ages*

Sample No.	Sulphides (as lead sulphide) per 15 gm. of dust		
	Fresh sample	1 year old	2 years old
		Gram	*Gram*
1	None.	0.0261	
2		.2043	0.2052

TABLE 4.—*Carbonate content in sulphur-lead-arsenate-lime dusts of various ages*

Sample No.	Carbon dioxide content per 15 gm. of dust		
	Fresh sample	1 year old	2 years old
	Gram	*Gram*	*Gram*
1	0.11	1.862	
2		.755	0.755

TABLE 5.—*Hydrogen-ion concentration in lead-arsenate-sulphur-lime dusts of various ages*

Material	PH	Material	PH
Freshly prepared dust	9.8	Calcium sulphite	7.6
1-year-old dust (light gray)	7.2	Calcium carbonate	6.6
1-year-old dust (black)	9.6	Calcium arsenate	9.8
2-year-old dust (black)	9.4	Water used in above tests	6.3

There is a slight increase in soluble arsenic during the first year's storage, as shown in Table 1. Very little or no increase was evident during the second year.

Sulphites, sulphides, and carbonates also increased somewhat during the first year and only very slightly during the second, as shown in Tables 2, 3, and 4.

The hydrogen-ion concentration increased somewhat during storage, increasing in a gray dust much more rapidly than in a black dust, as shown in Table 5. There was also a slight increase in the case of the black dust during the second year's storage. The reasons for this difference will be discussed later. As alkalinity in a fresh dust is due to the lime present, the decrease in P_H value during storage would seem to be due to the conversion of hydrated lime into calcium sulphite and calcium carbonate. This view is substantiated by the results of analyses and by the P_H of these salts in solution.

REACTIONS INVOLVED IN DARKENING OF A DUST

In an attempt to explain why some dusts darken more than others and the mechanism of the reactions involved, certain mixtures were made up in 200 c. c. of water and boiled. The mixture and the results follow.

Sulphur (C. P.) plus acid lead arsenate (C. P.)	No change in color.
Sulphur (dusting) plus acid lead arsenate (commercial).	No change in color.
Calcium oxide (C. P.) added to both of above while boiling.	Black lead sulphide formed.
Sulphur (dusting) plus acid lead arsenate (commercial) plus hydrated lime.	Black lead sulphide formed.
Sulphur (dusting) plus acid lead arsenate (commercial) plus calcium carbonate.	No change in color.

From these results it was evident that chemically pure chemicals went through the same reactions, and darkened in the same manner, as the commercial products, thus proving that the reactions were not due to impurities.

It was also evident that lime played an important part in the formation of lead sulphide and the consequent darkening of the mixture. The addition of calcium carbonate had no effect, a fact noted by Ginsburg (7).

Various dust mixtures were then made up, stored in paper bags in the laboratory for one year, and then examined. The results are given below.

Acid lead arsenate plus sulphur	No change in color; no sulphides, sulphites, or carbonates.
Acid lead arsenate plus hydrated lime	No change in color; large quantity of carbonates.
Sulphur plus hydrated lime	Small quantities of sulphides and sulphites; large quantity of carbonates; no change in color.
Acid lead arsenate plus sulphur plus hydrated lime.	Color dark gray; sulphides, sulphites, and carbonates present.
Acid lead arsenate plus sulphur plus calcium carbonate.	No change in color; no sulphides or sulphites.

The same results were therefore obtained in the case of dusts stored for one year as in the case of the boiled mixtures.

The first step, therefore, in the darkening of a dust probably involves the reaction of lime with sulphur to form calcium sulphide and calcium sulphite:

$$3Ca(OH)_2 + 3S \rightarrow 2CaS + CaSO_3 + 3H_2O.$$

This reaction would result in the formation of two molecules of the sulphide to one molecule of the sulphite. That this is approximately the case was shown by storing a mixture of lime and sulphur in an air-tight container and analyzing after six months. The results are given in Table 6. Complete agreement is impossible as the air can not be completely removed from a fresh dust.

TABLE 6.—*Ratio of sulphide to sulphite produced in stored lead-arsenate-sulphur-lime dusts*

Weight in grams, per 15 gm. of dust		Molecular ratio
Calcium sulphide	Calcium sulphite	
0.040	0.036	1.85 to 1.00.

Part of the calcium sulphide formed then reacts with lead arsenate to form black lead sulphide:

$$PbHAsO_4 + CaS \rightarrow CaHAsO_4 + PbS,$$

thus causing the dust to become gray to black, depending upon the extent of the reaction.

This would result in the formation of calcium arsenate. If this material is formed, there would be expected a very great increase in soluble arsenic upon digestion of the dust with water saturated with carbon dioxide (*9*). The darker the dust, the more calcium arsenate should be present and the greater the increase in soluble arsenic upon the action of carbonic acid. This was found to be the case, as shown in Table 7. A portion of the calcium arsenate here found is probably due also to direct reaction between the lime and lead arsenate, as suggested by Campbell (*2*), and possibly some to that between calcium carbonate and lead arsenate, as suggested by Ginsburg (*7*).

TABLE 7.—*Percentage of soluble arsenic in different colors of sulphur-lead-arsenate-lime dusts digested for six hours at 32° C. in water saturated with carbon dioxide*

Color of dust	Percentage of arsenic pentoxide which is water soluble
Light yellow	10.0
Light gray	11.9
Black	41.5

The large quantity of calcium arsenate in a black dust would also explain the difference in P_H between the light gray and black year-old dusts noted in Table 5, since calcium arsenate has a P_H approaching that of a fresh dust. Its formation would therefore tend to prevent great changes in the P_H value.

OTHER REACTIONS OCCURRING DURING STORAGE

The calcium sulphide not reacting with lead arsenate is apparently oxidized to sulphites:

$$CaS + 3O \rightarrow CaSO_3.$$

This is indicated by the fact that dusts stored in porous containers show a much larger quantity of sulphites than sulphides, the opposite being the case when stored in air-tight containers. A portion of the sulphites are probably formed directly by the action of sulphur dioxide upon lime:

$$S + 2O \rightarrow SO_2$$
$$SO_2 + Ca(OH)_2 \rightarrow CaSO_3 + H_2O.$$

Further oxidation probably results in the formation of sulphates, but no effort was made to determine this radical, as its formation is of little importance.

One other reaction of considerable importance also occurs, namely, that of the conversion of lime into calcium carbonate:

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O.$$

Moisture and concentration of carbon dioxide are the two main factors influencing the speed of this reaction. Although the concentration of carbon dioxide in the air is fairly constant, the tightness of the container and the porosity of the dust are factors influencing to some extent the concentration of gas available for reaction within the dust. Moisture is apparently the most important factor, the reaction taking place more rapidly under conditions of high humidity.

FACTORS INFLUENCING THE EXTENT OF DARKENING OF A DUST

The reactions causing the darkening of a dust may be summarized:

1. $3Ca(OH)_2 + 3S \rightarrow 2CaS + CaSO_3 + 3H_2O.$
2. $CaS + PbHAsO_4 \rightarrow CaHAsO_4 + PbS.$

The variables involved in the speed of the foregoing reactions are the concentration of hydrated lime, the temperature, and perhaps to some extent the moisture.

The factors influencing the concentration of hydrated lime at any one time are the quantity originally present and the extent to which the reaction given below has occurred:

3. $Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O.$

It has been previously shown that calcium carbonate will not react with sulphur to form sulphides. Therefore, the extent to which a dust will darken depends upon the relative speed of reactions 1 and 3. High temperature is the principle factor favoring the former, whereas porosity and high humidity favor the latter.

It would then be expected, and such was found to be the case, that a dust stored under very hot, dry conditions darkens much more quickly and to a much greater extent than one stored under cool, damp conditions.

CHANGES IN FUNGICIDAL AND INSECTICIDAL VALUE

The fungicidal efficiency of the dust changes very little, if at all, during storage as the greatest quantity of sulphur undergoing chemical change in any of the dusts tested was less than 0.5 per cent of the total quantity present. This quantity is considered too small to change materially its effectiveness, as Chase (*6*) records practically as good results in disease control in using 25 per cent less sulphur than is contained in the 80–5–15 formula.

A portion of the lead arsenate is changed during storage into calcium arsenate. As calcium arsenate has proved almost as effective an insecticide as lead arsenate, little or no decrease in insecticidal efficiency should result from storage.

FIELD SPRAYING AND DUSTING TESTS

As there was little or no change in insecticidal and fungicidal efficiency during storage, there yet remained to be determined the factor of safety as regards the plant to which the dust may be applied. As it has already been sufficiently proven that injury to fruits and plants is due to the arsenicals used, tests were conducted with calcium arsenate and lead arsenate both alone and in combination with the various buffer salts present in old and new dusts.

These materials were applied for comparative purposes as sprays since this method is much more accurate for small test plots. All materials were applied on the same day with a power sprayer to bearing 8-year-old Elberta peach trees.

Lead arsenate was used at the rate of 1 pound to 50 gallons, and calcium arsenate at the rate of ¾ pound to 50 gallons. Calcium carbonate and calcium sulphite were used at a calcium content equivalent to 4 pounds of hydrated lime to 50 gallons of spray. The results are given in Table 8.

TABLE 8.—*Spraying experiments with arsenicals, both alone and in combination with the buffer salts present in old and new dusts*

Materials used	Quantity per 10 gallons of spray	Effect on plants
	Grams	
Lead arsenate	90.8	Moderate defoliation; remaining leaves moderately burned; moderate fruit injury; no twig injury.
Lead arsenate	90.8	Very light defoliation; remaining leaves moderately burned; light fruit injury; no twig injury.
Hydrated lime	363.2	
Lead arsenate	90.8	Same as with hydrated lime.
Calcium sulphite	572.1	
Lead arsenate	90.8	Same as with lead arsenate alone.
Calcium carbonate	648.0	
Calcium arsenate	68.1	Almost complete defoliation; severe peach and twig injury.
Calcium arsenate	68.1	Moderate defoliation; moderate spotting on remaining leaves; severe fruit injury; no twig injury.
Hydrated lime	363.2	

A study of Table 8 leads to the following conclusions: (1) Hydrated lime greatly reduced arsenical burning in the case of both lead and calcium arsenates; (2) calcium sulphite prevented injury as well as did hydrated lime; (3) calcium carbonate was without effect in reducing burning; (4) calcium arsenate caused much more severe injury than did lead arsenate.

A 1-year-old dust of a light gray shade is therefore somewhat more likely to cause injury than a new dust; because a small part of the lead arsenate has been converted into calcium arsenate, and the remainder of the lime has been converted into calcium carbonate.

A 1-year-old dust dark gray to black is more likely to cause injury than either a new dust or a 1-year-old light gray dust, because a large portion of the lead arsenate has been converted into calcium arsenate and the remainder of the lime into calcium carbonate. The darker the dust, the more calcium arsenate is present and, therefore, the greater the danger of arsenical injury.

Elberta trees heavily dusted with these types of dust bore out these facts, as seen in Table 9. Frequent light rains and exceptionally high humidity made conditions especially favorable for burning. Only one application of dust was made.

TABLE 9.—*Dusting experiments with lead-arsenate-sulphur-lime mixtures*

Trees dusted with—	Effect on plants
New dust	No injury.
Year-old, light gray dust	Very light leaf spotting on few leaves.
Year-old, black dust	Light spotting on few leaves. Very light burn on 5 per cent of the fruit.

SUMMARY

The dark color of an old sulphur-lead-arsenate-lime dust is due to the formation of black lead sulphide during storage, the probable reactions being represented as follows:

$$3Ca(OH)_2 + 3S \rightarrow 2CaS + CaSO_3 + 3H_2O.$$
$$CaS + PbHAsO_4 \rightarrow CaHAsO_4 + PbS.$$

Varying quantities of calcium arsenate are formed in different dusts, depending largely upon the extent of the above reactions. The darker the dust, the more calcium arsenate there is present.

All hydrated lime not reacting with sulphur or lead arsenate is converted into calcium carbonate within one year or less.

The results of chemical analysis indicate that little or no change in insecticidal or fungicidal value during storage should be expected.

There is some increase in danger of injuring the plant from the use of old dusts; the darker the dust, the greater the danger of injury.

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